Author: Chamberlain, W.I.

Title: First principles of farming

Place of Publication: Pittsburgh, Pa.

Copyright Date: [19--?]

<2265626> *OCLC* Form:mono 2 Input:FMD
008 ENT: 990301 TYP: n DT1: DT2: LAN: eng
035 (OCoLC)40845298
037 PSt SNPaAg248.3 $bPreservation Office, The Pennsylvania State University, Pattee Library, University Park, PA 16802-1805
090 20 Microfilm D344 reel 248.3 $cmc+(service copy, print master, archival master)
100 1 Chamberlain, W. I.
245 10 First principles of farming
260 Pittsburgh, Pa. $bStockman-Farmer Pub. Co. $c[19--?]
300 87 p. $bill. $c24 cm.
500 Includes index.
533 Microfilm $bUniversity Park, Pa. : $cPennsylvania State University $d1999. $e1 microfilm reel ; 35 mm. $f(USAIN state and local literature preservation project. Pennsylvania) $f(Pennsylvania agricultural literature on microfilm).
590 Archival master stored at National Agricultural Library, Beltsville, MD : print master stored at remote facility.
590 This item is temporarily out of the library during the filming process. If you wish to be notified when it returns, please fill out a Personal Reserve slip. The slips are available in the Rare Books Room, in the Microforms Room, and at the Circulation desk.
650 0 Agriculture $xHandbooks, manuals, etc.
830 0 USAIN state and local literature preservation project. $pPennsylvania.
830 0 Pennsylvania agricultural literature on microfilm.

FIRST PRINCIPLES

OF

FARMING

By

W. I. CHAMBERLAIN, LL.D.

¶ A clear statement of the main scientific facts and laws that are fundamental in good farming. Adapted for the use of farmers in their homes and of teachers and pupils in our rural schools.

Stockman-Farmer Publishing Company

Pittsburgh, Pennsylvania

TO MY WIFE

¶Whose suggestions and criticisms have been an inspiration and a help in this and similar work for the past half a century.

REASONS FOR THIS BOOK'S EXISTENCE.

The scope and purpose of this little book are briefly given in its first paragraph. It was written at the request of its publishers to meet what seemed a real demand for a clearer statement of the facts and laws of chemical and physical science that underlie and explain the best agricultural practice. Most of the agricultural books already in print are by college professors, and are "above the heads" even of the more intelligent half of the farmers, using chemical and physical terms and formulas which presuppose a greater knowledge of science than even these possess. On the other hand a few agricultural books, mostly by practical men, do not explain the scientific facts and principles clearly enough to be a real help. This little book tries to pursue a middle course, as explained in its first paragraph. And lest the writer's study of the sciences in college, sixty years ago, and continued since only by reading, should not conform to the advance in science since then, he submitted the principal chemical parts of the manuscript for suggestions to Professor J. S. Chamberlain of the Massachusetts Agricultural College, the principal geological parts to Professor G. F. Wright of Oberlin College, Ohio, and the principal physical portions to Professor H. H. Hosford of Doane College, Nebraska, each one a specialist along the line submitted to him. And while he gladly acknowledges his indebtedness to them he does not hold either of them responsible for any possible lack of clearness, or any lack of conformity to the latest teachings of science. He would also make grateful mention of Professor Alfred Vivian's book "First Principles of Soil Fertility," which he has found a great help in his work, and from which he has drafted a few cuts, by permission.

On carefully re-reading this little book in its final proof sheets, the writer is led to hope that it will not only be a real help to farmers, but that it may be adopted as a helpful text book for study in many of our rural schools.

W. I. CHAMBERLAIN.

Hudson, Ohio.

CHAPTER I.

THE SCOPE OF THIS WORK.

The writer desires to give a clear statement or story of what our soils contain, how they were formed and modified, how plants grow in them, what food they require, the nature of useful and of harmful plants, how we make the plant food more available by tiling, tilling, manuring and fertilizing the land; and to give a clear definition or explanation of the many scientific words or terms found in agricultural papers and books. That is, to explain scientific terms and to make as clear as possible the more important facts and scientific principles which underlie farming as a successful business, so as to help the readers by understanding those principles to farm more successfully. And he hopes to put it all in such clear and simple language that any bright farm boy, girl, man or woman who has graduated in "the three R's" in district school can understand better than ever before "the why" of farm facts and practices, and therefore more easily can master "the how" of it all. But the reader should always have a good dictionary close at hand and look up every word he does not fully understand.

THE OBJECT OF FARMING.

We farm, or should farm, in order to "raise things," but only such things as, under our circumstances, will sell at best profit to us, to supply the wants of men and beasts. We raise plants from inorganic plant food in the soil and air in order to feed beasts and to help feed and clothe man, because plants alone can feed upon the plant food in soil and air and prepare from them and store up in themselves food and clothing fit for man and food fit for beasts. We raise beasts to work for man and to help feed and clothe him. Plants therefore come first in necessary and in historic order, because, as stated, they can and do feed upon the inorganic or unorganized or non-living elements in soil and air, a thing which men and beasts cannot do.

ORGANIC FOOD.

Men and beasts, as implied above, must have organic matter for food, that is matter which has already had organic life, vegetable or animal. Farm animals feed mainly upon plants; men feed upon both plants and animals. Is that clear? "Organic" food is the "energy food" of living organisms. It consists of three kinds of compounds: Carbohydrates (carbon and water) such as sugar,

starch, etc., contained in soil and plants; fats, as in butter, fat meat, etc., and in the plants that produce them; and the proteins or albuminoids, like the white of eggs, the gluten of wheat, the curd of milk, etc., and the plants that produce these. The first two, in animals and men furnish chiefly the muscular force or energy and the animal heat; the last goes chiefly to make the blood, muscle, lean meat, etc., and, with lime and phosphorus, the bones. The carbohydrates are chiefly composed of carbon and water (remember the "hydr" part of the word means water, as in "hydrant"). The fats are almost wholly carbon (inflammable, heat producing). The proteins or albuminoids are largely nitrogen, named from albumin, the Latin name of the white of an egg (rich in nitrogen), the first half of the word meaning simply white. All living cells must have this energy food. Plants make it for their own use from the nitrogen and the carbonic acid and water which are in the air, and from the mineral elements in the soil. Men and animals cannot make their own energy food from soil and air, as before stated, but must get it ready-made, or in organic compounds, from plants and from other animals.

WHAT PLANTS FEED UPON.

To return to the plants: Plants feed upon certain non-organic "elements" in soil and air, either free or in combination. An "element" in chemistry is a form or kind of matter which cannot by any means yet known be separated into two or more unlike parts or elements. In earth and air some 78 "elements" are now known to chemists. Some are gaseous, like oxygen, hydrogen, nitrogen, etc., to be described later; some liquid, like quick-silver; some solid like gold, iron, silver, etc., and the countless chemical combinations of these 78 chemical "elements" make up every known form or kind of matter, solid, liquid, or gaseous, now existing in earth, sea, lake, river and air. Most fortunately the farmer, even the truly scientific farmer, needs, as a farmer, to study and understand only ten of these 78 elements; and only three or at most four even of these ten are likely ever to run short in his farming or require his attention. These are the ten: nitrogen, phosphorus, potassium (potash), and calcium (lime), carbon, oxygen, hydrogen, magnesium, iron and sulphur. Three more are sometimes found in plants, but seem not to be essential. These are chlorine, silicon and sodium.

THE "ESSENTIAL ELEMENTS."

These ten elements are really essential, but, as stated above, only the first three, or at most four, are likely ever to run short in farming, namely, nitrogen, phosphorus, potassium and calcium. These four and some of the others are commonly known by the names of the combinations in which they are most sold for agricultural purposes, viz. (for the four), ammonia (nitrogen and hydrogen), phosphoric acid (phosphorus and oxygen), potash (potassium and oxygen), and lime (calcium and oxygen). These are compounds, not elements, but are often somewhat inaccurately called elements, for convenience.

DESCRIPTION OF THE ELEMENTS.

Now, boys, study hard, as you would over a difficult lesson in school, and try to get a good working knowledge of or acquaintance with these ten, and especially with the four essential elements and learn their nature and the work they do in agriculture; for you will very often meet their names in these articles and in all agricultural books and papers, and each name should convey a clear and distinct idea, as do the names cow, hay, etc.

NITROGEN.

This element is a gas, very slightly lighter than air. It has neither color, taste, smell nor resistance to touch. It is perceptible to none of our five senses and therefore very hard to "get acquainted with." Only chemists can "perceive" it and they can do so only by certain laboratory tests; and those who are not chemists can know it only by what the chemists tell us, or in its various combinations, or by its known effects upon plants. It occurs "free" as an element in the air, mixed (think of mixing clover and timothy seed) but not chemically combined with oxygen and a few other gaseous elements in minute quantities together with carbonic acid (carbon and oxygen), to be described later. When chemical elements combine the compound is different from either; when they mix, each retains its own nature. It forms about 77 per cent by weight of the air and is slightly lighter than the air. The remaining 23 per cent, by weight, of the air is almost entirely oxygen, which is slightly heavier than the air. The carbonic acid and other gases make up an almost inappreciable part of the air, though the carbonic acid as a total is wholly sufficient to furnish all the carbon needed by plants. As nitrogen occurs in the air it is very inert or inactive and is not available as plant food, except through the soil by the bacteria in the tubercles or white bunches on the roots of plants, as will be explained later.

Nitrogen combines and forms two compounds, which are distinctly different, and in both of which it is present in the soil and in fertilizers, and either directly or indirectly is available as soil-food for plants. Combined with oxygen and hydrogen it forms nitric acid. When this nitric acid exchanges its hydrogen for metals like potassium, sodium or calcium, it forms solid salt-like compounds, known as "nitrates." It is only in this form (of nitrates) that nitrogen is actually used by plants as food, except by the clovers, as already mentioned. A common nitrate is nitrate of soda, or "Chili saltpeter," which as a refined compound contains about 16

per cent of pure nitrogen, by weight. The other compound of nitrogen is ammonia of which a little over 82.3 per cent is nitrogen and a little less than 17.7 per cent is hydrogen. Ammonia is a gas which in solution in water is known as "aqua ammonia," the common cleansing liquid of the druggists. Ammonia is the sharp, pungent gas given off smelling salts and also from the fermenting urea of horse manure, the nitrogen of the urea in turn having been derived from the protein (nitrogenous) feed eaten by the horses.

In clean, dry raw bones there is about four per cent of nitrogen and in dried blood about 13 per cent. In fresh-mixed animal manure there is less than half of one per cent and in commercial fertilizers usually from one to four per cent; the amount contained being required by law to be stated on each sack, usually in its equivalent of ammonia. All these organic compounds decompose in the soil and yield up their nitrogen as ammonia, which in turn is changed by bacteria (to be described further on) into nitric acid. All this is hard to understand. It cannot well be made plainer here, but it will be far better understood if it is carefully reread after reading a few chapters that are to follow.

In its effect on plant growth, nitrogen is the element whose abundant presence in available form does most to give the dark green color and rank growth to corn and other plants, and whose shortage makes them look yellow and sickly. Foods and feeds rich in nitrogen are called "protein" or "albuminoid" feeds; for example: meat, eggs, whole-wheat bread, etc., for men, and the clovers, wheat bran and cottonseed and linseed meal, etc., for beasts. Nitrogen enters largely into the blood, bones, muscles and tendons of animals and men, and into the milk and wool of animals, and therefore these require "protein" or "albuminoid" feeds, especially sheep and milch cows and all young and growing animals and children for they are daily increasing their blood, muscle and bone. More of this last in future chapters.

CHAPTER II.

PHOSPHORUS.

In most agricultural writings phosphorus is usually mentioned and rated as "phosphoric acid." This last is a compound of phosphorus, oxygen and hydrogen, and is the form in which it is used by plants in fertilizers and manures, and the form and name by which its percentages are, by law, printed on all fertilizer sacks that claim to contain it. Phosphorus itself is a whitish and very inflammable substance, which is caused to take fire and burn by the heat generated by a little friction against a rough substance, and hence it was long used (and still to some extent) on the tips or ends of friction matches, where it may be seen and touched. The word "phosphorus" comes from the Greek, and literally means "light-producing." "Lucifer" from the Latin means exactly the same, and hence the name "lucifer matches." Phosphoric acid composes 20 to 24 per cent of dry animal bone, and this amount all animals and men must get from their food, and this the plants that the animals eat must therefore get from the soil; and the plants and animals that men eat must get it directly or indirectly from the soil. The young of all suckling animals must get the phosphorus for the first few months of the growth of their bones, teeth, etc., from their mothers' milk, their only food, and therefore these mothers must have phosphorus in their feed to give phosphorus to their milk. The office of this element in plant growth is, in part, to hasten maturity, improve the grain of cereals, and especially to help form the bran. As already implied its office in animal life, together with lime, is to form the bones and bony or horny parts.

POTASH.

This is a compound of the true elements potassium and oxygen. The name potash (the form in which it occurs most in nature and in commerce) is used by nearly all agricultural writers instead of the pure "element" potassium, and is also used on fertilizer sacks because the percentage of "potash" and not of potassium is required by the laws of nearly or quite all of the states. Hence the term "potash" will be used in these articles to save confusion. Potash was formerly made by leaching wood ashes and boiling the lye in "pot-ash" kettles until a whitish solid or granular substance resulted which was therefore called "pot"-ash. "Caustic" potash may be got at the druggist's. It looks like white chalk blackboard crayons, and is used to "burn" the coming horns on calves and prevent their growth, for "caustic" means capable of burning something. Its full office in plant growth seems not to be so clearly known, but it cer-

tainly is the predominant valuable part of the ash of woody plants, and it forms a part of the acids of most fruits and is supposed to add brightness to the color, especially of apples. Tobacco requires very much potash, and potatoes and cabbages use somewhat less than tobacco but more than most other plants and hence are known as "potash crops." Its purchase in fertilizers is usually wise for sandy or mucky soils, but is seldom wise for clayey soils, which are usually rich in potash.

The present source of nearly all of our commercial potash is the vast deposits of crude potash salts near Stassfurt, Germany, enough to supply the wants of agriculture and commerce for centuries. The refined and recrystallized sulphate and muriate of potash look much like common coarse salt, and each contains about 50 per cent of "actual" potash, in a condition almost as soluble as common salt. The cost of these three most important kinds of plant food in commercial fertilizers, in normal times, is about as follows: Nitrogen, rated as ammonia, 15 cents per pound; phosphoric acid, 5 cents per pound; potash (actual) 5 cents per pound. But the European war has greatly advanced the price of the German potash salts and sent up the price of phosphoric acid and of ammonia considerably. For further study of these three elements see future chapters on commercial fertilizers.

LIME.

This is not an "element" but a compound of the elements calcium and oxygen. Every one has seen (and felt) the lime of commerce in its burned form, used in brick laying and plastering, and also to help increase plant growth on some soils. Most soils contain enough of it for the food requirements of plants. It is not therefore regarded or sold as a fertilizer or plant food, but to sweeten sour or acid soils, and to hasten the decay of crude humus or vegetable mold and make its nitrogen and other inert plant food more readily available. If any soil when well drained, tiled, fertilized and tilled refuses to grow clover it is probably "sour" or "acid" and needs 500 to 1,000 pounds per acre of burned lime (fine-ground or slacked) or 1,000 to 2,500 of finely-pulverized limestone to sweeten it or correct its acidity. Alfalfa seems to require applied lime more generally and in larger amounts than any other crop.

CARBON.

This is the part which (chiefly) burns in coal, wood, straw, tallow, etc. Wood-charcoal and anthracite coal are nearly all composed of carbon except their ashes and some earthy matter in the anthracite. Plants get their carbon wholly, or nearly so, from the carbonic acid in the atmosphere, and the supply is constantly replenished (as will be seen) and is practically inexhaustible. The carbon part of the "humus" (vegetable mold) now in the soil, or

added in the green manure and stable manure, though not used to any extent by the roots as plant food (since plants, as stated, get their carbon through their leaves) is nevertheless quite valuable because of its mechanical effects in making the soil more loose and spongy, more retentive of "capillary" or "film" moisture and more easily entered by and more inviting to the roots of plants. More of this in the chapters on manures and fertilizers.

OXYGEN AND HYDROGEN.

These two invisible, intangible, very light gases combine to form the visible, tangible and quite heavy liquid, water. The ways of chemical compounds are past finding out. Oxygen also mixes but does not combine chemically with nitrogen to form our atmosphere, as explained before. It is necessary to combustion or burning. We open the stove or furnace draft and the oxygen of the air unites with the carbon of the coal and makes it burn when lighted. Men and animals breathe the oxygen of the air through their nostrils, and fishes breathe the oxygen of the water through their gills and the oxygen in both cases makes possible the slow combustion of the digested and assimilated food; and it is this slow combustion, especially of the carbon part, which furnishes the heat and muscular energy of man and beasts. Oxygen and hydrogen combined and forming water, and oxygen combined with all the other nine essential elements, together with carbon, make up (see Vivian's Soil Fertility) 98½ per cent of our mature but undried corn plant, and about the same per cent of other mature but undried agricultural plants.

SULPHUR, IRON AND MAGNESIA.

The first is a solid, well known to our sight, touch, taste and smell. It enters into all farm products to some extent, and quite largely into some, as for example onions and the eggs of fowls, as is seen in the latter case by the blackening of a silver spoon when we eat cooked eggs with it. It is the sulphur that blackens it, just as the sulphur of a friction match will blacken a silver watch in the same pocket with it. Iron is a solid, well known to all by sight and touch. It enters into all plants very slightly, in the form of iron oxide (iron combined with oxygen), but that small portion is essential. Magnesia (a compound of the "elements" magnesium and oxygen) as found at the druggist's is a white powder, slightly caustic. It is often found in considerable proportions in limestone rock and in burned lime. It is considered a damage to the lime for agricultural uses, though a little magnesia is essential to plant life and healthy growth.

Now, boys, re-read these two chapters and try to fix in mind what these ten "essential elements" are and how they behave in agriculture.

CHAPTER III.

WHERE AND HOW PLANTS GET THEIR FOOD.

We have thus far tried to make the reader fairly well acquainted with the ten "elements" or kinds of food in soil and air which all agricultural plants must have to feed upon. Next let us inquire in what form and by what means the plants "eat" their food.

The part that comes from or through the soil must be wholly in liquid form or condition; in "solution," or dissolved—in thin soup, so to speak. None of their food can the plants take in solid particles, as it was once believed they could and did. The soil if properly tiled, tilled and fertilized, is made up of countless small grains or particles, each covered and charged with what is known as "film" or "capillary" moisture, to be explained further on. Between these particles are minute, otherwise empty, air-spaces or irregular pores.

ROOT HAIRS.

Through these pores the roots of growing plants push downward and spread out all through the soil, thickly covered all around and near their advancing ends with many very fine, live "root-hairs," so called, which have countless little "mouths," so to speak, which drink in film moisture through their membranes by what is called "osmosis" from all the soil particles, holding in solution nine of the ten elements of food that the plant must have.

THE SELECTIVE POWER OF PLANTS.

Each plant has what may be called the power of selection, namely the remarkable power to take what it needs and no more of each element, if the soil contains it, including even its own peculiar flavor and odor, both from soil and air. We don't know how. Thus an acre of tobacco requires thirteen times as much potash as an acre of wheat does. But wheat and tobacco will grow luxuriantly side by side in the same rich soil and each take just what potash, nitrogen, etc., it requires and no more, provided the soil and air contain enough of all the elements required and in available form. So too twenty or more varieties of apples have sometimes been grafted and grown on one apple tree, and each variety gets its own peculiar color, texture and flavor from the same soil and trunk and the same air, sunshine and rain. Is not this a wonderful world?

All these points will be explained and illustrated more fully and interestingly farther on, each in its proper place. Thus much seemed necessary at the first in order to prepare the way to understand better what is to follow.

PLANT FOOD FOUND IN THE AIR.

Agricultural plants (with few exceptions) get their food from the inorganic (or non-organized) matter and gases of the air and the soil. Farm animals, we repeat, cannot feed upon this inorganic (non-organized) food or original chemical elements or simple chemical compounds found in air and earth, but must have it "organized" for them by plants, and must use it before it is "disorganized" into its original chemical elements or simple compounds by combustion or decay or bacterial action.

Wheat roots, showing earth adhering to root hairs. After shaking, the earth adheres only to the root hairs. Higher up the root hairs have mostly fallen away.

For our purpose in this book this is the one great distinction between plants and animals. Plants feed upon inorganic food (non-organic, that is, not at present "organized" into a living plant or animal). Farm animals must have their food "organized" for them previously by plant growth, and men must have theirs previously organized for them by plants or by other animals feeding on plants. Formerly the words "organic" and "inorganic" were used in the above sense by the chemists, and this is still the popular sense, the sense in which the words will be used in this book. This clear explanation seems necessary, because the chemists now commonly use the two words in a different and technical sense.

From the air originally but now almost wholly through the soil by their roots, as already described, though partly through their

leaves plants get their water, which is a liquid compound of the two gases, hydrogen and oxygen, two of the ten "essential elements" (see chapters I and II). The water comes in rain, dew and fog; the rain used chiefly through the roots, the others partly through the leaves. The individual farmer cannot greatly control or increase the amount of rain received on his farm, but he can and should control its proper reception, storage, saving and availability in the soil, and its economical use by plants, as will be shown in future chapters. And he will increase the leaf use of dew and fog by increasing the amount of leaf exposure, and of fine earth to absorb it.

THE SOURCE OF CARBON FOR PLANTS.

From the air the plants also get practically all of their carbon, in the form of carbonic acid or carbon dioxide, which is a gaseous compound of two of the ten essential elements, carbon and oxygen, one solid, the other gaseous. In the form of carbonic acid the carbon is absorbed by the leaves of plants, and under the sun's light and heat and of the green matter (chlorophyll) of the leaves and together with hydrogen and oxygen it goes to make up nearly all the combustible part of the plant in solid form, the part that will burn. Fix it in mind that carbon makes up the main part of whatever will burn and give off heat. In burning, the plant returns to the air whatever parts came from the air. The parts that came from the earth remain on the earth as ashes. Remember, too, that about 98½ per cent of the mature, undried agricultural plant comes from the air, being built up from the water (hydrogen and oxygen), the carbonic acid (carbon and oxygen), and the nitrogen. Oxygen is combined also in some form with each of the other ten essential elements named and explained in chapters I and II.

The supply of carbonic acid in the air is practically inexhaustible by plants, partly because it is so large in total amount and partly because it is replenished about as fast as it is drawn upon, by all the combustion, breathing, decay, etc., on the earth's surface, all of which release carbon into the air as carbolic acid. The farmer therefore need pay no attention to its supply, nor fear its exhaustion. All he has to do is to see that the soil has an abundant supply and in available form of the three (or four) essential elements which are likely to be lacking in available form or condition, and the plant will get its own carbonic acid.

THE SOURCE OF NITROGEN FOR PLANTS.

The clovers and other legumes get a considerable portion of their nitrogen each year from the "free" (uncombined) nitrogen of the air, but even this considerable fresh supply from the air they must take indirectly through the soil, made available by the agency of certain microscopic growths called "bacteria" found in the "nodules" or bunches that grow on their roots. All other plants

except the legumes get practically all of their nitrogen from the supply of it in the soil, slowly stored there in considerable quantities from its vast storehouse in the air, in past ages down to date, by means and agencies to be explained hereafter.

Now, the supply of available nitrogen in the soil is liable to exhaustion below the point of most profitable farming. The farmer, therefore, should certainly increase the new supply from the sky by growing in short rotation some of the clovers. He should also return the nitrogen drawn from the soil in crops by carefully saving and returning all he can of it in the manure of the animals that eat the plants, and in order to increase the supply he should buy and use commercial fertilizers, which are the wastes of civilization and the stores of past ages, to supplement but not to supplant the clovers and farm manures, as will be fully explained in the chapters on rotation, manures and fertilizers.

CHAPTER IV.

PLANT FOOD IN THE SOIL.

The elements described in Chapter II all came originally or directly from the air, as there stated. The rest of the ten essential ones to be used as food for plants are found in the soil; and all of them are found there stored in sufficient quantities to last man and beast for centuries, provided they are properly handled. The total supply ever to be had is already in soil, mines, waters and air. And as stated, it is sufficient, if properly used. Whoever made this big round world did not mean to have its thinking inhabitants starve. The food and fabric elements are all here, subject to man's intelligent use, sufficient if properly handled. And the sciences that underlie agriculture as an art tell us how to handle and use them properly, that is, so as not to exhaust their available supply below the point of the profitable production of all needed plants and animals. The art of agriculture should try so to practice the teachings of science and experience as to enable the farmer to earn a good living from the soil without excessive toil, and yet not exhaust or diminish, but even increase, its productiveness, that is, its available plant food. The object of this little book is to explain, in the simplest language possible, the principal and most useful teachings of agricultural science along the line of conservation.

THE SOIL; WHAT IS IT, HOW FORMED, HOW BEST FARMED?

Every bright farm boy knows that the word "soil" as commonly used means the rather thin, dark-colored, porous layer at or near the surface of the earth. It is partly made up of "humus" which means vegetable "mold" or decaying vegetation, mixed with the harder subsoil somewhat by moles or other earth animals and by earth worms, water or ice action or other agencies of nature before and since man came to do the farming. Its depth in any locality depends upon the amount of vegetation that has decayed there or been brought thither by wind, water or glacial or other action, to be described further on. The formerly timbered soils of Ohio, Indiana, etc., are from five or six to twelve or fifteen inches deep, made up largely of decayed and decaying leaves, twigs, limbs and trunks of the tree growth of centuries. The soils of Illinois and other prairie states are twenty to thirty-six inches deep, or even more, made up largely of the rank grasses that have fallen and decayed there for many centuries, aided by the other natural agencies already mentioned. Certain "alluvial" and "lacustrine" soils to be described later are still deeper.

THE SUBSOIL.

Under the soil is the subsoil as the name indicates. It is composed almost wholly of mineral matter, that is, it is not mixed to any extent with decaying organic matter, or "humus." It is usually yellowish in color for a few feet down, from the action of oxygen upon the original blue clay where the soil is clayey. It is more compact and less porous than the soil. It contains all of the mineral or soil elements of plant food but very little nitrogen or carbon from humus, though it contains carbon in the form of carbonate of lime for example.

THE RESULTS FROM BURNING PLANTS OR ANIMALS.

When a plant, animal or other carbonaceous body is wholly burned, all those elements in it which originally came from the air return to the air in the form of smoke, steam, vapor or gas; and practically all that came originally from the soil, that is the so-called mineral parts, remain in the ashes and return to the earth whence they came. Matter is said to be indestructible and eternal. That is, you may change its form but it does not cease to exist. If you collect in a close retort, as chemists often do, all that part of a plant which in burning would otherwise escape into the air, and weigh all of it and of the ashes with care, the two together will weigh just what the original plant or other body did, plus the oxygen used or combined in the burning. Thus it appears that the earth and air and sun-influence at present contain all the ten elements of plant food, and that there has been no loss from the sum total of the world's original supply in soil, air and sunshine, only a change in place and combination. But the plant food has some of it left our fields where it is needed and gone to the cities where it is not needed as future plant food, but is a nuisance, polluting air and water. As far as possible it should all be returned to the soil, whence it came.

HOW WERE SOIL AND SUBSOIL FORMED?

The geologists who study the earth's formation, and its geological history in the remote past ages, have found and given to the world convincing proofs of certain facts, briefly stated as follows: Very many centuries ago this earth was a molten mass, somewhat like the melted lava which in these days is sometimes poured forth from the craters of volcanoes.

KINDS OF ROCK.

Its surface very, very slowly cooled, forming what the geologists call "igneous" or "fire-formed" rocks. Granite, gneiss, trap and modern cooled lava are examples today of igneous or fire-formed rock. In this country they are found largely in New England. "Aqueous," "sedimentary" or water-deposited rocks came later,

formed from the crumbled grains of igneous rocks, carried and deposited usually in strata or layers, by water-action. Sandstone, limestone, shale, etc., are good examples of aqueous rocks. "Metamorphic" rocks are those whose original form or structure has been changed later, especially by heat, or by chemical action, by pressure or otherwise, making them harder and more crystalline in structure. Examples are the slates, formed in thin layers by pressure from shale or clay; marble, formed from aqueous or common limestone, etc. Metamorphic rocks have little relative importance in agriculture, but much in commerce and the arts.

EARTH'S ROCKY CRUST A VAST STOREHOUSE.

It is worthy of special note, repeated here, that the earth's original crust of igneous rock must have contained somewhere all the mineral or ash elements that would ever be needed by man in agriculture or in the arts or commerce, and whose countless chemical combinations with each other and with the elements in air and sunshine make up the material of everything on and in the earth and air now or in the past or the future.

Also that the sun and the air and the "ether" and earth furnish the possibilities of an unlimited and ever-ready supply of all the forces or forms of energy that will ever be needed, including gravitation, wind and water power, steam and gasoline power, muscular power and electrical and chemical energy, ever needed or to be needed in man's agriculture, inventions, manufacturers, transportation and commerce. Was it lucky chance or an All-seeing, All-powerful and All- loving Being that provided for this world's people in rich abundance all conceivable material and force that they could ever need in all the ages of their development?

CHAPTER V.

AGENCIES THAT FORM THE SOIL.

UNDERSTANDING A MACHINE.

You can work a machine with real success only when you understand fairly well its materials, its construction, the proper function or use of each of its parts, and the power that works it. Take a twine-binder reaper for example. You must understand the wood, steel, iron and canvas and how they are made and combined, the strength and the strain upon each part, the use or function of each, the power that moves all, and the mode of transfer and distribution of the power. Your horses furnish the power. As they move their power slowly turns the drive-wheel and its cog or chain-gear transfers the power to the cutter-bar, canvas, elevator, packer, twine tension, knotter, twine cutter, and to the "kicker" that sends the bundle to the carrier, which at your will delivers the bundles conveniently for shocking. The inventor and the maker of the machine have carefully tested and thoroughly know the strength of each part and its "factor of safety" above the hardest strain that ever need come upon it; but you too must understand all this practically, lest by foolish adjustment or careless driving, lack of oiling or some other folly or ignorance of yours the willing and well-made machine refuses to work or even breaks some important part.

So, also, in the proper management of his greatest and most complicated machine, the elements and forces of soil and air, the farmer, in order to be really most successful, must understand their materials (which have been already explained in part), the construction, or how made, the function or proper use of each part, and the great power or powers that run the machine. So we must study next how our soils were formed.

WHAT CRUMBLED EARTH'S ROCKY CRUST?

This solid igneous rock of earth's original crust, even when cooled (see Chapter III), could not at all support our present agricultural plants. Its surface must first be broken and ground up fine, that is pulverized, and have nitrogen and carbon and oxygen and hydrogen in some way added from their chief source, the air.

THE WORK OF COOLING, IN BREAKING THE ROCKY CRUST.

As the earth slowly cooled it shrank, as a heated tire shrinks in cooling and binds the wheel. If made too small before heating, the tire will crush the wheel or break the tire itself. Just so this spherical "tire" or band of cooling, rocky crust shrank so much that the molten mass lower down resisted compression, broke the tire and itself bulged up into mountain ranges, causing depressions else-

where that became the beds of oceans, seas, lakes and ponds and the valleys for streams. These mountains and valleys seem to us immensely high and deep, but as compared with the earth's size they are less than the roughness of the "peel" of an orange as compared with its size.

THE WORK OF THE SUN IN BREAKING THE ROCKY CRUST.

Also the heat of the sun by day and the cooling by night, and its heat in summer and the cooling in winter, alternately and to different extent, swelled and shrunk the different elements of the rocky crust differently, causing chasms, cracks and crevices, large and small.

THE WORK OF OXYGEN AND CARBONIC ACID.

Into these cracks and crevices, and even into the small pores, the oxygen and the carbonic acid of the air freely entered and combined with the elements of their rocky sides. Oxygen is one of the greatest and greediest "mixers." As we have seen, it combines with all the nine other essential elements of plant food; and it combines also with many others of the 78 chemical elements. It oxidizes iron and rusts it, and lead and tarnishes it. It combines with hydrogen and the two light gases unite to make a heavy liquid, water. It mixes with nitrogen and forms the air we breathe. It oxidizes shale and blue clay near the surface and makes them yellow. The reason why clay remains blue and more compact deeper down is that the air with its oxygen cannot reach it. This illustrates how oxygen and carbonic acid (carbon and oxygen) enter the cracks and crevices and porous parts near the surface and help to pulverize the rocky crust.

THE WORK OF WATER AND ICE.

Water, too enters the cracks and crevices and pores, and its carbonic acid helps cut and decay their sides. Cold turns the liquid, water, into a solid, ice, and this in forming expands and splits the rocks up finer. You may have seen shale rock that had been quarried or dug with pick and mattock in hard, solid fragments from a new cellar excavation, and thrown out upon the surface near by, reduced to fine, soft sticky blue clay by the freezings and thawings of a single winter.

THE WORK OF STREAMS.

Streams form, and roll and rub and grind the larger, rough fragments into rounded pebbles of all sizes and deposit them as coarse gravel near their source and, as they are ground finer and finer, carry them farther and farther from their source and deposit them in layers successively of gravelly sand, coarse sand, fine sand, clay and loess. Such are some of the ways in which water helps to form a soil from rock.

THE WORK OF PLANTS.

But agricultural plants must have nitrogen, and that, reluctantly as it would seem, comes from the air, not from the rock. And so, certain lower forms of plant life, such as the lichens and mosses, seem to stand ready to get a foothold and grow at first where there was little but solid rock. These had the power to bring down what little nitrogen they required, year by year, from the air, or to take that brought down and stored in minute quantities by rains and thunder storms year by year, and decaying they left it and the carbon from the air in the small amount of "humus" they formed. And so, later, larger plants and even some forms of trees grow, and their roots crowd down into the crevices of the rocks, and year by year slowly wedge the rocks apart more and more, as we see them doing now, and admit more water and more ice. By these and other like agencies a fairly fertile soil was slowly formed containing all the essential soil food.

THE LENGTH OF TIME REQUIRED.

Nor did it probably take so long as some of the earlier geologists seem to have believed. Near ancient Pompeii, which was buried more than 18 centuries ago by an immense eruption chiefly of a sort of coarse earthy ashes from Vesuvius, the present writer in 1908 saw rank gardens and vineyards growing on decomposed rocky lava thrown out by an eruption of Vesuvius which recent or current history says occurred less than half a century before. So rapid comparatively is soil formation from hard, igneous rock at the present time. No doubt it was far slower at the first, but, perhaps, not so slow as the earlier geologists supposed.

CHAPTER VI.

THE GREAT GLACIAL ACTION.

A GREAT CALAMITY; A GREATER BENEFIT.

After most kinds of agricultural plants, trees and early animals were growing and living in the northern temperate and the torrid zones and probably even in the warmer parts of the northern frigid zone, in the warmer carboniferous ages, a vast, deep sheet of snow-ice slowly formed in the frigid and the north temperate zones, not only in North America but in Europe and in Asia. But we shall hereafter speak only of the North American glacier. This vast ice sheet pressed slowly southward, a few feet or scores or possibly a few hundred feet each year. Most of the geologists seem now to be convinced that the cause of this vast ice sheet, together with the slow cooling of the earth, was an upheaval or gradual elevation of the northern part of the globe, even as mountain ranges elsewhere were elevated, as we have before described. This great upheaval lifted the already frigid zone and much of the north temperate zone up into the region of eternal snow like the tops of mountains now lying further south. For centuries apparently the snow accumulated there, until it was several hundreds or even thousands of feet deep (or high) and its immense weight slowly solidified its lower levels into a deep, somewhat pliable or easily-bending snow-ice, and the combined elevation of the land beneath and of its own depth or

height slowly pushed the vast mass towards the lower, warmer regions, just as today the smaller but still very large glaciers or sheets of snow-ice in Greenland, Alaska and Switzerland are pressing slowly towards the lower, warmer regions and towards the sea. In Greenland today there is a vast glacier or sheet of snow-ice more than a mile deep, which covers about thirteen times the area of Ohio, pushing slowly outward from higher levels, and as its front edge slowly and gradually projects over the sea it breaks off at intervals in immense fragments which float southward, some of the larger ones before they melt away reaching even into the pathway of the great ocean liners from America to Europe, bringing danger and sometimes disaster to them. It was one of these huge icebergs from Greenland that sunk the immense Titanic.

THE GLACIATED AREA OF NORTH AMERICA.

The heavy line near the bottom of the map shows the "terminal moraine" or southern limit of glacial action. Where solid black it shows where the southern limit has been definitely located.

THE EFFECTS OF THE PREHISTORIC GLACIAL ACTION.

This vast prehistoric continental glacier pressed slowly forward for centuries, destroying all vegetation, sweeping large trees into valleys and burying them, where they are still found in excavating or in digging wells, driving slowly southward the primitive animals that then existed, grinding rocks to fragments, rounding, smoothing and partly leveling hills, rising even above the tops of the highest of the White Mountains and covering and somewhat smoothing the Green Mountains and the Adirondacks. This huge glacier carried soil and large and small fragments of rock in or beneath its mass, especially in and under its lower levels, for miles and even for scores and hundreds of miles, scattering them southward both above and below the surface of the so-called "till" or "boulder clay." These are roughest and most numerous near the hills and mountains from which they were torn by the glacier. Hence the very rocky, stony surface of the land in New Hampshire and other mountainous states.

Each long winter the great ice sheet advanced a good deal and each short summer it melted back considerably, causing great streams which carried the sand and the finer clay far southward and left the coarser gravel nearer the glacier's southern edge. Such are the main facts as believed by the great geologists.

SOME PROOFS OF THE GREAT GLACIAL ACTION.

There are several clear proofs: (1) Scratches or grooves from less than an inch deep up to several feet in the top of sandstone and limestone and other hard bed-rock, exactly like the grooves now cut

by the rocks bedded in the bottom of present-day glaciers. (2) Granitic boulders of all sizes on the surface and 30 or more feet deep in the subsoil in regions where no granite bed-rock exists, but exactly like the granite bed-rock far north, whence they came as is shown by exactly matching these fragments with the Canada bed-rock for color and texture. (3) The buried trees found 50 to 80 feet deep in digging wells nearly as far south as Cincinnati, Ohio. These trees are found with bark, wood and seeds well preserved in form by the exclusion of the air, just as canned fruit is now preserved, by excluding the air. (4) The rounded and smoothed surface of the hills and the more smooth and level surface of all glaciated land as compared with the non-glaciated land of similar origin and of similar character otherwise. (5) The mixed non-stratified "drift" soils, composed of all the elements of the soils that lay in the path of the great glacier. The writer has seen with his own eyes all these five proofs, except the third, and is convinced by them and other proofs that the great geologists are correct in what they believe and say about the glacial action as the only agency that can explain the observed facts. Its action was of vast importance to our present agriculture as will be shown later.

THE EXTENT OF THE GLACIAL ACTION.

The great glacier evidently extended over all of Canada from ocean to ocean and over the north half of the United States. Its southern edge or limit, before it slowly melted back to Greenland (for causes, reversed, like those that brought it on, namely a depression of Arctic levels)—this southern limit is marked by a line of low hills made up of till or boulder clay and called the "terminal moraine," composed of the mixed stones, gravel and earth pushed forward at and near or under the front of the glacier and left there as the ice melted back. This terminal moraine has now been pretty accurately traced westward along about the middle of Long Island, New York, nearly due west, near New York City, through New Jersey; slightly north of west through the eastern half of Pennsylvania into the southern edge of New York state near Lake Erie, deflected northward, probably by the Alleghany Mountains; thence southwest through western Pennsylvania and entering Ohio near Beaver, Pa., and Lisbon, Ohio, and southwest through Ohio until it crosses the Ohio River just east of Cincinnati; thence nearly due west just south of Cincinnati, through southern Indiana and Illinois and south of St. Louis; thence northwest nearly parallel to and 100 miles or more southwest of the Missouri river and onward to the Rocky Mountains and even to the Pacific Ocean. See glacial map on page 24.

A BLESSING IN DISGUISE.

It destroyed all vegetation and drove all early animals southward before it; but as it slowly melted back later under warmer

climatic conditions, plants, animals and men slowly followed it and found a far better and more fertile soil for agriculture. For the surface had been stirred and mixed to a depth in Ohio of 20 to 50 feet or down to bed-rock in many places, as proved by granite boulders found at those depths, and by the composite and non-stratified character of the soil and the subsoil. That is, for 20 to 50 feet down the "drift" or boulder clay contains in it all the elements of plant food, indeed practically all the chemical elements contained in all the rocks and the soils over which the glacier had passed and which it had laid under contribution. And statistics of crops, in Ohio at least, where the present writer compiled and compared them with great care, together with other data, seem to show that it added about 50 per cent to the value of the land over which it passed, as compared with near-by land originally similar but over which the glacier did not pass. Of such vast significance and benefit to agriculture was the glacial action. I have, therefore, often wondered that most writers on soils have given the subject only brief and passing notice.

CHAPTER VII.

KINDS OF SOIL.

Names to denote their origin. For convenience in writing and talking about them all soils are logically divided, to indicate their mode of formation, into the two great classes "sedentary" and "transported" soils.

SEDENTARY SOILS.

Sedentary or stationary soils are those that have "weathered" wholly from the underlying bed-rock, no part of them having been transported or brought to their present location by water, ice, wind or other agencies. Such soils are just as good in mineral plant food and no better than the underlying rock from which they are formed. If that rock is mainly limestone they are usually quite productive; if it is mainly sandstone they are somewhat less productive; if it is mainly shale they are much less productive.

TRANSPORTED SOILS.

These are those many or most of whose particles have been carried (transported) to their present place by the action of ice (glaciers, see Chapter VI) or of the water of seas, lakes or streams or sometimes by wind.

DRIFT SOILS.

These are the soils that have been transported and mixed by the great glacial action already described (see Chapter VI). Such soils are a mixed mass, not usually assorted for size of particles, or stratified, that is spread in layers like "alluvial" soils.

ALLUVIAL SOILS.

These are those that have been assorted for size by the more or less rapid movement of streams and deposited in layers or "strata" and according to the size of their particles; the coarser gravels being dropped soonest, from the more rapid currents, and the sands and clays farther on from slower and still slower currents. These alluvial soils are found along the courses of rivers and smaller streams both in the glaciated and the non-glaciated regions. Usually the "second-bottoms," so-called, of large streams, lying above the level of present highest overflow, are doubtless the alluvial deposits of the much larger, wider and deeper streams that resulted from the final rapid melting away of the great glacier, and from the heavy rains that accompanied and helped to cause that melting. Alluvial soils are usually very fertile, especially in the glacial regions

and along the sides of rivers that flow southward from glaciated regions, or rivers in limestone regions.

LACUSTRINE SOILS.

The finer sandy, lime and clay soils that formed at the bottom of shallow lakes or arms of the sea that have since dried up or been filled up by their deposits or by some geological change, are sometimes for convenience distinguished from alluvial soils and called "lacustrine" soils from the Latin word "lacus" which means a lake. When, as often occurs, such deposits are solidified into rock, they are of course called "aqueous" rocks (see Chapter IV). Such rocks are usually easily quarried in nearly horizontal layers, as they were deposited, and often clearly show the ripple marks or wave marks of the water. Many of our best soils west of Lakes Erie and Michigan are apparently the lacustrine deposits from small lakes that no longer exist, much humus having been added by water plants.

FURTHER CLASSIFICATION OF SOILS.

For convenience, also, other names are sometimes given to soils to describe more fully their character and composition, etc., as follows:

GRAVELLY SOILS.

These are made up largely as their name indicates of gravel and small pebbles rounded by water-action and deposited from a relatively swift current. The gravel contains some sand. If they come from limestone they are usually quite productive, as along the Miami River in Ohio. If from sandstone or shale, mainly, they are less productive, as along the Cuyahoga and Muskingum rivers in Ohio.

SANDY SOILS.

These are soils in which coarse or fine sand forms the principal part, both of soil and subsoil, the sand having been deposited by currents of water slower than those that deposited the gravelly soils; or sometimes those that were ground up by glacial action into sand from a nearby sandstone ledge lying in its pathway towards the north. Such soils feel gritty to the touch when rubbed between thumb and finger and thoroughly scour the plow and other tillage implements, and the grains of sand though, usually somewhat mixed with humus, can be seen with the naked eye. Peaches seem to do best in such soils, especially if lime is abundant in them. They are usually deficient in potash.

CLAYEY SOILS.

These are those whose principal part has come from the decomposition of argillaceous or shale-clay rock. Their particles are smaller than those of finest sand and cannot be seen separately

without the aid of a microscope. The particles are so small that they will float a long time in water, making muddy water which very slowly settles into clear water. Such soils are usually rich in potash in their original composition, and the glaciated clays were made richer in it from the ground-up granitic rocks of the glaciation. That is why clay soils seldom require or justify the purchase of potash as mentioned in Chapter II. They are very retentive of water and usually are much benefited by tile drainage. They are sometimes hard to be permeated by the roots of plants and trees, which therefore spread out near the surface except where tile drainage is pretty thorough.

MUCK SOILS.

These are made up largely of partly-decayed vegetable matter, with too little mineral or earthy matter, especially too little potash, for general crops. But if the actual muck is not over two feet deep or so, and if it lies directly above a clay subsoil, and if they are drained of their surplus water to a depth of about two feet, and supplied with needed potash, they make most excellent soils for celery, lettuce, onions and cabbage; and in many sections, especially of Ohio and Michigan, considerable areas of such soils are used almost exclusively for growing these and similar crops.

PEAT SOILS.

These are, like muck soils, made up chiefly of vegetable mold, but far less decomposed than muck soils. They were formed in swamps and are made up mainly of water plants. These plants are so little decomposed in the "peat bogs" that they are often cut out in cubes and used for fuel where coal is scarce. They are not good soils for crops and hardly deserve to be called "soils" at all, for they contain very little available plant food.

LOAMY SOILS.

These contain a mixture of sand and clay with a good deal of humus, the sand being in sufficient proportion to the clay to prevent its being too sticky and non-porous. A true loam is one that contains nearly equal parts of sand and clay. A "sandy loam," so-called, is a loam that contains more than half sand, aside from its humus. A "clay loam," so called, is one that contains more than half clay, aside from its humus. A true loam, with about half and half of its mineral part composed of sand and of clay, and with an abundance of humus, is perhaps our best land for general farming, provided it has plenty of lime in it from underlying limestone rock or brought to it from limestone regions by glacial action.

CHAPTER VIII.

AGRICULTURAL PLANTS.

The soil is the main feeding ground of plants and trees, useful, useless and harmful in farming. In it their roots spread and brace, to enable their stems or trunks to stand up and grow in the air and bear up against the fierce winds that sometimes blow. From or through the soil by means of their roots or the bacterial nodules on them, as already explained, they drink in, in solution, all the ten essential elements of plant food except carbon. This last they absorb almost wholly from the air through their leaves, in the form of carbonic acid. The air and the soil and the deposits of past ages contain enough of all the essential elements of plant food to supply the needs of agricultural plants for centuries to come, and even to permit the farmer gradually and constantly to increase his soil's productiveness, provided his soil is properly managed so as to make the inert plant food available, and the crops are properly rotated, and provided the available wastes of our farms and our cities and the rich accumulations of nitrogen, phosphoric acid, potash and lime, stored in past ages, are properly conserved and applied to the land, and provided the air is forced to yield its nitrogen to the soil through our clovers, fitted by nature to do that very work. How to do all this is the problem worthy of the best study and action of our bright farm boys and girls, laying under tribute, as they must, the latest and best results of our trained workers in all the sciences that underlie agriculture. How to make a generous living from the soil without excessive and benumbing toil, and without diminishing, but rather increasing, the soil's fertility for coming generations, is a most interesting problem, as before hinted.

We have already studied the soil, its origin, formation, modifications and contents, and the air and its contents of plant food, and are now ready to study the principal plants and crops that grow from elements in soil and air before we tackle the hard problems of most profitable farm management.

VARIOUS CLASSIFICATIONS OF PLANTS.

First for our purposes, let us divide all plants into the two great classes of the useless and the useful, or the harmful and the helpful.

USELESS OR HARMFUL PLANTS.

These are the so-called weeds. A weed is sometimes defined as "a plant out of place," or in the wrong place. In that sense self-sown clover, timothy or millet plants which sometimes spring up

thick in a field of potatoes or corn are "weeds," and sometimes they are quite troublesome; but we never think or speak of these naturally most useful plants as "weeds."

THE ORIGINAL PURPOSE OF WEEDS.

What we mean by "weeds" is, plants that are almost never useful but nearly always harmful in man's agriculture. The popular names of some of those familiar to and hated by every farmer and farm boy are as follo—: Ragweed, pigweed, tumble-weed, fox-tail or barn-grass, purslane, plantain, English plantain, gill-run, ox-eye and yellow daisy, dock burdock, cockle, beggar's lice, stick-tight, wild carrot, wild morning-glory, thistle, Canada thistle and many others that farmers hate and fight. It is said that Nature never forms or creates anything without good purpose, and weeds were apparently intended to clothe the earth with verdure" and increase its available plant food, and prevent the waste of plant food, by storing in their own bodies that which was available and subject to waste, and, dying, rot and leave it as humus on and in the soil. To make them most useful for this purpose Nature made them hardy growers, great seed bearers and wonderfully equipped for scattering their seeds. A large hard maple (not a weed but a tree designed to "clothe the earth with verdure") may bear very many thousands of seeds, all equipped with wings to spread themselves over the waste places and change them to beautiful groves and forests. Dandelion and thistle seeds have a sort of balloon attachment to float them far and wide with every wind. Burdocks and beggar's lice and stick-tights stick to man and beast and are carried and dropped far and wide by them. Every farm boy knows how the seeds of weeds are scattered, and what a nuisance weeds are to the farmer.

For when and wherever man manages the growth of plants, he grows far better and more useful plants; and weeds become a nuisance, with no usefulness unless it be to compel the farmer to cultivate his fields early and often for the destruction of the weeds, and thereby reap the other vast benefits of tillage. The best means of preventing and of destroying weeds will be studied in future chapters on tillage, on cover crops and on rotation.

USEFUL PLANTS.—CLASSIFICATIONS.

These are those that help supply the wants of men and beasts, as before noticed in Chapter I. Every farm boy knows several classifications. The most common and obvious one perhaps is the following, according to their uses.

FOOD AND FEED CROPS.

These include: (a) Forage crops, the grasses, clovers, corn fodder, etc. (b) Grain crops or cereals; corn, wheat, rye, barley, etc. (c) Root and tuber crops; the carrot, beet, turnip, potato, sweet potato, etc. (d) Fruit and nut crops; including tree fruits and nuts, bush fruits, vine fruits, apples, pears, stone-fruits, berries, grapes, etc. (e) Vegetable crops, such as the tomato, bean, pea, lettuce, celery, cucumber, melon, etc.

FIBER OR CLOTHING CROPS.

These include hemp, flax, cotton, jute, sisal, etc.

ORNAMENTAL OR FLOWERING PLANTS.

These include the tulip, narcissus, lilac, rose, lily, sweet pea, peony, aster, chrysanthemum, dahlia and almost countless others that beautify our homes and gardens.

TIMBER CROPS.

These include the oak, chestnut, walnut, butternut, etc. (also nut-bearing or food-producing trees), maple, etc., etc.

CLASSIFICATION FOR LENGTH OF LIFE.

Annuals: Plants that produce their seed the first season and then die and need new seed planted for each new crop are called annuals.

Biennials: These live two years, produce seed the second year and then die and must be reseeded. These include most of the clovers, beets, turnips, etc.

Perennials: These live several years without reseeding. The above two special classifications are the most obvious and the most common and useful ones to the farmer.

CLASSIFICATION AS TO SOIL EXHAUSTION.

This general classification is, for our purposes, quite a useful one. It divides all useful agricultural plants or crops into two great classes, the exhaustive crops and the recuperative ones. The exhaustive crops are those commonly called the "money crops." The recuperative crops are the clovers, which add nitrogen from the air as already explained in part in Chapter III and to be more fully explained in the chapters on Rotation with Clover. These should not be sold directly, but fed on the farm and the products sold, and are indirectly money crops.

THE EXHAUSTIVE OR "MONEY" CROPS.

These are the crops commonly sold from the farm directly or indirectly, that is, sold entire or fed wholly or in part and the products of feeding sold.

Of course, crops like flax, hay (if sold), potatoes and other vegetables and especially tobacco, that are sold directly and entire

or nearly so, are the most exhaustive ones even of the so-called "money crops." Flax, where both fiber and seed are sold, as is usually the case, removes all but the stubble and roots. The same is true of hay (the grasses) if sold rather than fed. Potatoes and other vegetables remove all but the tops. Tobacco removes all but the stubble, roots and stalks or stems and sometimes even the stems are sold or not wisely used on the farm as a fertilizer. These crops therefore probably remove from the farm more than any others of the money crops, say from 50 to 70 per cent of all the plant food that the entire plant drew from or through the soil, or from the air, except, of course, the carbon, not counted as a costly element.

CROPS PARTLY SOLD REMOVE LESS PLANT FOOD.

Such crops are the cereals. If only the grain is sold directly, and the straw and stalks or roughage are fed or used as bedding to absorb all liquid manure, and if all the bedding and manure are carefully saved and wisely used on the farm, then probably such crops remove from the farm about 30 to 35 per cent of the valuable plant food they took from its soil and air. They are certainly less exhaustive than the former class.

THE "FED CROPS" ARE LEAST EXHAUSTIVE OF THE THREE.

These include the grasses (hay) if fed on the farm; corn, if stalks and ears are all fed on the farm, as silage or otherwise; and all root crops, mangels, turnips, etc., fed on the farm. These probably if wisely handled remove from the farm not more than about 20 to 25 per cent of the essential and valuable plant food which they took from its soil and air. Professor Vivian (Soil Fertility, p. 120) says 20 per cent. Some chemists say more. The reason for this is somewhat as follows: Farm animals can digest and assimilate only about 20 per cent of the total value of the plant food (contained in the plants) which they eat. This 20 per cent they make into animal heat and other energy, blood, muscle and bone, and into their valuable products such as milk, wool, meat, strength for work, etc. The other 80 per cent approximately which they cannot thus utilize goes into their total manure, which if all saved, both liquid and solid, by means of water-tight floors and gutters and straw and other absorbents, may all be returned to the soil of the farm whence it came.

CHAPTER IX.

RECUPERATIVE PLANTS.

THE CLOVERS.

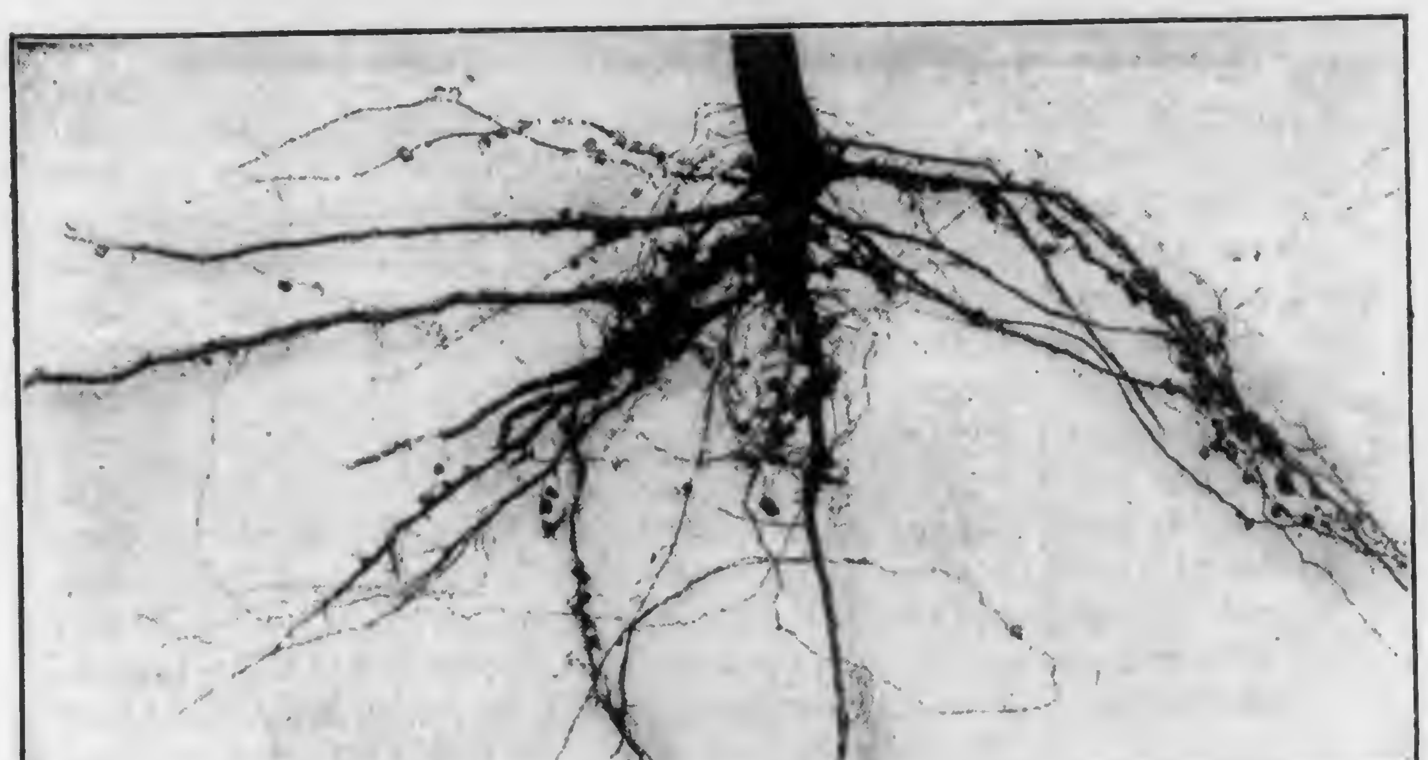
The clovers are the principal recuperative plants used in agriculture and their study is a most interesting and wonderful one. They belong to the wide family of the so-called "legumes," but the clovers are the only members of that family much used by farmers north of 39 degrees of latitude as recuperative crops. The clovers include the common red clover and the English or mammoth clover, the two most used of all in rotations of crops to replenish the land after two or three exhaustive crops, like wheat, oats, corn, potatoes, tobacco, etc. (see Chapter VIII). Other legumes sometimes used as recuperative crops are alsike clover, sweet clover or melilot, cow peas, soy beans and alfalfa. The chief and most valuable peculiarity of these plants is that they alone of agricultural plants have the power of using as plant food the "free" or uncombined nitrogen of the air. The air is a mixture, not a combination, of 77 per cent of nitrogen by weight (see Chapter I) and 23 per cent oxygen by weight (see Chapter II). The nitrogen is called "free" because it is simply "mixed" and not chemically combined, or its nature changed, just as milk and water will mix and not change the chemical character of either. In its free state nitrogen cannot be used by most plants. It may help us to remember the facts if we compare it in a rough way with the free or wild horses of the plains (which are hard to catch), and if we say that clover is the only lasso or lariat with which it can be "caught." Clover is sometimes called "a trap for nitrogen."

VAST STORES OF UNAVAILABLE NITROGEN.

How vast are the stores of nitrogen in the air may be seen by a little figuring. The air weighs (has a pressure over a vacuum) nearly 15 pounds to the square inch, and 77 per cent of that weight is composed of nitrogen, or 11.55 pounds to the square inch. But there are 6,042,240 square inches in an acre, and available nitrogen in fertilizers is ordinarily worth 15 cents per pound and much more in these war times, and this multiplied by 11.55 equals $1.73 as the value of the nitrogen floating over every square inch of land. And this multiplied by 6,042,240 gives $10,453,075, the value of the nitrogen mixed in the air that presses upon every acre of our land at sea level, provided it could be made available and provided there were a market for such vast quantities. For if such vast quantities were available it would be as cheap as the waters of the ocean. It would bear no price, since every one would have all he wanted of it,

VERY SMALL RELATIVE AMOUNTS AVAILABLE.

The amount of nitrogen available as plant food even through the agency of the clovers is exceedingly small as compared with this immense total amount; just as the proportion of salt ever boiled out of the water of the vast ocean is relatively small but is really large if all used, and it would be sufficient for the wants of man if there were not cheaper sources of salt than boiling it out of ocean water. Just so the nitrogen that can be utilized as plant food through the agency of the clover roots by plowing the crop under, or feeding and returning the manure, is sufficient for the needs of



Nodules on Roots of a Soy Bean Plant.

agriculture as supplementary to other sources. And the fortunate thing is that utilizing it thus is not an expensive process like boiling salt out of ocean water, but the nitrogen is a by-product, so to speak, of clover. For long before they knew that clover "trapped" nitrogen from the air men grew it as a crop profitable in itself, especially as a paying feed-crop and for its loosening effect on soil and subsoil, and as the cheapest protein feed when pastured; while they blindly felt that in some mysterious way it makes the soil more fertile where it grows.

HOW DOES CLOVER ACT?

In two general ways: It brings nitrogen from the air and makes it available, and it gathers much inert plant food of all sorts from deep down in the soil, makes it available, stores it in its big tap root and in its top growth, ready as food for animals and, later, as food for other plants that cannot thus collect it and make it

available from earth and air. For many years the chemists declared that the clovers (and other legumes) could not and did not increase the total supply of available nitrogen for plants. They were misled by the natural but incorrect supposition that if the plants get nitrogen from the air at all it must be through their leaves, as they get their carbon; then the chemists proved that the clover plants do not take it through their leaves and therefore they inferred that they do not get it at all. But still the practical men insisted that a crop of clover, whether plowed under or fed and the manure returned to the land, leaves the soil richer than it finds it. Finally certain chemists attacked the problem biologically, and Professor Atwater of Connecticut first proved the fact of actual increased nitrogen brought from the air, and Dr. Helreigel of Germany first showed the method or means by which they get it, viz., by the means of minute microscopic living organisms called "bacteria" (little rod-like plants) that work in and through the nodules or bunches that form on the roots of clover, converting the unavailable nitrogen that comes to the roots through the air pores of the soil into plant protein, an available form of nitrogen. The cut herewith is from a photograph of nodules on soy bean roots. This seems "ancient history" to the boys and young farmers nowadays, but the knowledge has all come within the memory of men now hardly past middle life, and we have all learned to dig up carefully the roots of clover, alfalfa, soy beans, melilot, etc., and gently and carefully wash away the soil and actually see the little whitish bunches or "nodules" or "excrescences," about as big as a clover seed and larger, sometimes hundreds of them on the roots of a single plant. We cannot see the actual bacteria that do the work, for it takes a powerful microscope to see them, since they are so small that several thousands of them can "sit" side by side in a line in the length of an inch!

THE GREAT IMPORTANCE OF THE CLOVERS.

Thus much of the outside knowledge of what these minute bacteria in the nodules on the roots of legumes really do for us has come to us through the long-continued and patient researches of the chemists and the biologists. Let us be truly thankful to them for it. To reduce it to the most simple language of illustration, it has been shown conclusively that a good crop of clover one year in each four-year rotation will supply enough available air-and-soil nitrogen for the three other crops of the rotation, say the corn, oats and wheat, provided all manure that belongs to the soil is returned to it, and provided the clover is plowed under or fed and the manure returned. For, as intimated above, clover not only brings down nitrogen from the air, but brings it and other plant food up from too deep in the subsoil for the roots of the shallow-growing

crops to reach it. In a three-year rotation the clover one year furnishes more nitrogen for each of the exhaustive crops than in a four-year or a five-year rotation, and may even add to the total stock of available nitrogen.

THE ROTHAMSTED EXPERIMENTS.

Certain experiments of Lawes and Gilbert at Rothamsted, England, showed that available nitrogen from nitrate of soda sown on the land is inclined to soak or leach down even three or four feet and escape in the tile drains. The clover roots drink it in even from the depth of four feet and prevent its escape and bring it back to do its duty—even as Jonah was brought back when he was fleeing from Nineveh. Again: It was seen in Chapter VI that the boulder clay, stirred and mixed to a depth of 20 or even 50 feet, was just about as rich in the various mineral elements of plant food at 20 feet deep as at two feet deep, and the clovers, especially the far deeper-running alfalfa, can bring parts of this mineral plant food up and, decaying, leave it in their large tap roots in available condition as food for shallower-growing crops. The clovers are one of the richest gifts of God to the farmer. They are the foragers and scavengers for less predacious crops. Dr. J. G. Holland, in one of his novels, makes an Irishman sing the praises of the pig somewhat thus: "The peg is the aiconomicalest little baste that aiven the Lord A'mighty Himself iver made; fer, doan't ye see, the peg kin ate wut there won't nothin' ilse ate (swill, garbage, etc.) and thin ye can ate the peg!" The same is true of the clovers. They are the foragers and scavengers for all the other crops. They eat from soil and air what no other plants can eat, and store it in their big tap roots, and when they die and decay the other plants can eat their stored plant food.

WHY NOT USE CLOVER MORE?

Since, then, the clovers are most valuable forage plants themselves, and since they store up as a by-product increased quantities of available food for other plants, I cannot see why all farmers do not use them more and in shorter rotations. Since they are the key to unlock the vast stores of air-nitrogen, I cannot see why farmers do not use this key more freely, instead of paying 15 cents per pound for nitrogen.

CHAPTER X.

FOUR FUNDAMENTALS IN FARMING.

The four chief fundamentals or essentials in all good farming are draining, tilling, manuring and rotating. That is the natural order. If the land is not naturally drained you can do no good farming, that is growing of crops under cultivation, until it is drained in some way, and "farming," that is, cultivating crops, pays better than grazing, as will be seen later.

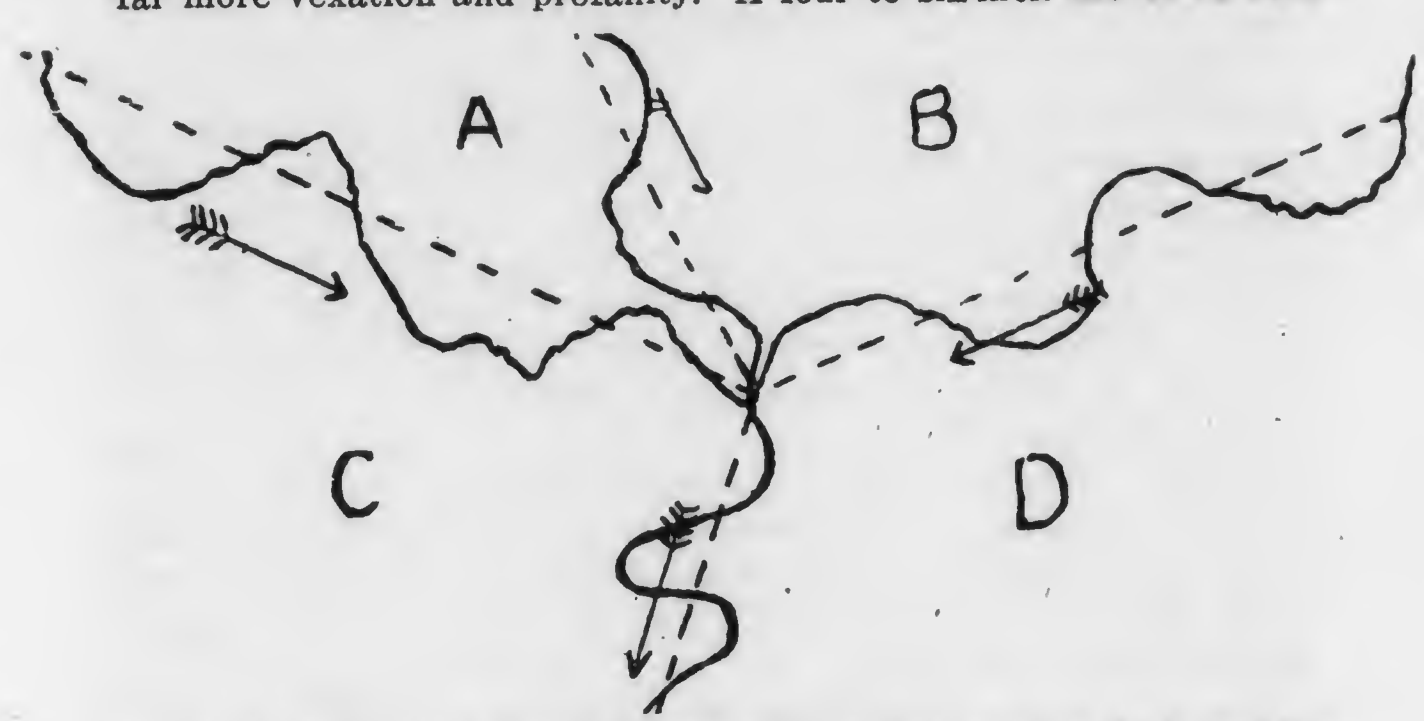
DRAINAGE.

Fortunately our sandy and gravelly soils and subsoils are underdrained by nature and need no artificial drainage unless there are wet swales or small cat-swamps. But wherever there is a very level, compact clayey soil, there a pretty complete system of tile-drainage is needed before cultivated crops, including clover in rotation, can succeed. We drain such land with tiles, then, to remove surplus water. What is surplus water? It is that which stands stagnant on or in the ground, after heavy rains or thaws, long enough to injure wheat, corn, potatoes, clover, etc., and perhaps kill them. For the roots of our agricultural plants must have air as well as moisture, and they must have moisture rather than water; that is, "film" or "capillary" moisture rather than stagnant water, for the latter excludes the vital air which plant roots as well as man's lungs must have.

CAPILLARY WATER.

Film or capillary water (moisture) is that which adheres to the small particles of earth or of sugar or of a sponge or of a lamp wick, and makes the water (or oil) rise in soil or sponge or wick considerably above the level of the stagnant water (or oil) in which its lower end or part is placed. Dip the small corner of a cube of white cut-sugar into coffee (whose color shows its rise better than water would) and capillary attraction will rapidly lift the coffee through the whole cube. In the same way the oil in a lamp is lifted by capillary attraction perhaps two or three inches above the oil in the lamp. So also, and by the same force, the film moisture is lifted and kept in the soil sometimes two or more feet above the stagnant or "free" water or "ground" water below. After a heavy rain the water fills all the larger air spaces in the soil and excludes the air. If the land is underdrained, naturally or with tile, this "surplus" water soon settles, under the force of gravity, to the level of the stagnant or "ground" water below the tile, and leaves the proper air spaces open as they should be from surface to tile, and the capillary force holds the capillary or film moisture clear up to or near the surface where it should be to feed the plant roots. First, then, we drain with tiles, where needed, to remove the harmful surplus water. That is the one fundamental purpose of drainage. Its benefits are of several kinds:

(A) It improves the shape and increases the area of many fields for cultivation. For example, let the cut, herewith, represent a large field, with the crooked lines representing depressions or "dry brooks" where water stands or slowly flows for several days after heavy rains, so at to prevent cultivation and even drown out crops if planted. This field must be cultivated and cropped, if at all, in four crooked plots A, B, C, and D, (see cut), with crooked sides, less total area, and far more and sharper corners to turn, and far more vexation and profanity. A four to six-inch tile down each



crooked swale (see dotted lines) will pay its cost tenfold, making the swales the dryest, richest parts of the field.

(B) Tile drainage lengthens the crop season. It dries and warms the land for tillage and planting earlier. It warms it earlier because the warm rains soak down through the open air spaces, whereas if the land is not drained these spaces are full of water and ice in the spring, all of which must be melted and evaporated before the soil can begin to become warm enough and dry enough for plowing and planting and tillage to begin; and both thawing and evaporating are slow and tedious processes and tend to keep the land cold. Thawing ice with salt freezes the ice-cream. Sprinkling the floor cools the kitchen or porch.

(C) Tile drainage, where needed, saves waste of manures, fertilizers and soil plant food. Where land that needs it is not tiled the water of heavy rains and snow-thaws floods off on the surface, carrying much plant food in solution, and even washes away some of the best of the soil itself. But where the land is tiled the surplus water passes down through the larger pores of the soil, which filters it and sends it out through the tiles clear and pure and with very little plant food in it, and no actual soil.

(D) Tile drainage increases the area of root pasturage. Roots will not go much below the level of frequent "free" water or

"ground" water, say six or eight or ten inches in stiff, undrained clayey soil. But if it is tile-drained 30 inches deep or more they will go to the depth of the tiles for there is no stagnant water above that line to close the air spaces. Sometimes drainage means life for wheat, potatoes, clover and young fruit trees, and lack of it means death. Striking examples of this have occurred on the writer's own farm.

(E) Tile drainage greatly aids tillage and pulverization, by making the land dry enough earlier, sooner after rains, later in fall and nearly all the time, to pulverize or make into fine soil fitted to the spread and growth of roots.

(F) Tile drainage greatly diminishes the effects of heaving and winter-killing of wheat, clover, etc., by hoar-frost or stool-frost. The writer's farm and many others that he has seen have furnished abundant proofs of this. Winter-killing by frost-heaving practically ceased when the tiling was completed. It took away the surplus surface-water which had made the stool-frost form before, which heaved the wheat and clover.

(G) Tile drainage where needed makes rotation of crops possible, with wheat, corn, potatoes, and clover, thereby greatly increasing the net farm income, as will be shown in the chapter on rotation, and helping maintain and increase fertility.

(H) Tile drainage where needed greatly helps crops to resist drouth. This may seem strange, but it is true, as clearly proved by experience. The reason is plain. It gives the plants an earlier, thriftier start and makes them more advanced in growth and stronger to resist drouth if it comes. Further: A clay soil, not drained, tends to settle down and become too soggy and compact. A sponge with a corner in water and the rest held loose out of the water will lift and hold a large amount of capillary water, but squeezed to half its size it will hardly hold half as much. And this loose, spongy condition of a soil that is well tiled fits it to hold a far larger reserve of water in case of drouth. These are only a part of the reasons why tiling pays on heavy clay soils.

THE WORK OF TILING LAND.

This will not be treated in this book which is intended more as an explanation of the sciences that underlie agriculture; the reason why rather than the methods by which farm operations are carried on. Those who wish instruction in the practical work of draining land should get a special book on the subject. The cheapest and most up-to-date one I know of, and on the whole the best for the average farmer, is one published by the A. I. Root Co., of Medina, Ohio. It pays one to buy it. It costs very little and it fully explains the reasons why, and the means and methods, the tools and machines, by which we do the work. Special hand-books will pay on almost every department of agriculture and horticulture.

CHAPTER XI.

TILLING THE LAND.

DOES TILLAGE PAY BEST?

In preceding chapters it was assumed that the tillage of cultivated crops pays better than grazing with permanent pastures and meadows for livestock. We must now try to prove it. We assert that tillage with crops pays best, because it will produce more food and feed and other needful things, will support a larger population and give a larger net annual income per acre or square mile than permanent pastures and meadows or any other way of using the land.

This is a mere assertion, but history proves that it is a fact and science shows the reason why. First, history. In savage life with hunting, fishing, eating spontaneous vegetables, nuts, berries, etc., it took several thousand acres to support each family. In the nomadic state of the Patriarchs, with flocks and herds and their meat and milk, etc., and a very scanty primitive agriculture, it took several hundred acres. Under modern agriculture a hundred acres, and under intensive farming (tillage) and vegetable and cereal growing, as in Belgium and other densely-peopled countries, a square mile supports more than 700 people, or more than one person to each acre, and even Ohio supports 125 people to the square mile, or one person to each 5 acres, and exports large amounts of food, wool and other necessities and luxuries. Thus all history down to date seems to show that tillage pays best, that the plow is the basis of abundant food-production and of civilization.

By "tillage" as we use the word here, is meant the breaking up and stirring of the upper eight inches of the soil, more or less, with the plow, cultivator, harrow, roller, etc., to prepare for planting crops, or for the cultivation of crops after they are planted. Now, why and how does tillage as thus defined pay best? In general we may say it does so because it renders available each year more of the inert plant food of soil and air than mere pastures and meadows can, and uses it to better advantage. It does this for several reasons and in several ways:

(1) IT INCREASES "ROOT-PASTURAGE."

It does this by making the soil finer, looser, more moist, giving better access for the roots and root hairs, already described and pictured (see Chapters III and IX), and increasing the film moisture that adheres to the particles and permitting it to yield up to the root hairs the plant food held in solution, as was explained in Chapter III.

(2) IT RETARDS EVAPORATION.

Tillage increases the available plant food because it prevents evaporation and waste of needed film moisture or capillary water.

A DRY-EARTH MULCH.

This refers to the light cultivation with the weeder or the slant-tooth harrow in preparing for a crop or, after corn or potatoes are up, which creates a so-called dry-earth mulch and prevents the escape and waste of moisture. It does this for the following reasons: Capillary attraction brings the moisture to or near the surface just as fast and no faster than it is taken. We want the root hairs to take all of it for growth. Then it is used and not wasted. For if the capillary attraction brings it clear up to the surface, the sun and the wind will take it, just as the flame takes the oil in the lamp as fast as the capillary attraction in the wick brings it up to the surface of the wick. But if sun and wind take the water, it is wasted. And just as we put out the light of the lamp in the daytime so as not to waste the oil, so should we always as far as possible put sun and wind out of commission in the daytime (the only time they waste much moisture) by a dry-earth mulch which breaks the capillary tubes, so to speak, and prevents their pumping the moisture clear up to the surface, where it could be wasted by sun and wind. Just how the dry-earth mulch does this you can see if you sprinkle a little pile of granulated sugar on top of a cube of cut loaf sugar, and dip a corner of the cube into coffee. Capillary attraction will take the coffee all through the cube but it will stop near the edge of the dry-sugar mulch, because the capillary tubes are practically broken there.

WHEN TO USE THE DRY-EARTH MULCH.

Whenever in a dry season a shower makes a wet crust on the surface it restores the capillary tubes clear to the surface. As soon as the surface is dry enough again, the harrow or the fine-toothed cultivator or the weeder should be used lightly, to break the capillaries by restoring the loose dry-earth mulch. Or in a dry August and September when preparing the seed bed for wheat each day's plowing should be rolled and lightly harrowed to make a dry-earth mulch. Also after each light shower until seeding time. Scarcely anything pays better than thus to keep a dry-earth mulch in a dry season.

(3) TILLAGE AERATES THE SOIL.

It increases productiveness by letting the air into the soil more freely and thus helping the bacteria to decay the humus and make its inert nitrogen and other plant food available. This fact rests on proof understood by chemists and bacteriologists. Those who

are not "up" on these sciences must take it on the testimony of those who are. The fact of an increase we can ourselves see. The reason we take on faith.

(4) TILLAGE DESTROYS WEEDS.

Tillage increases the soil's productiveness because it destroys weeds, if rightly managed. Before planting, tillage implements, especially the weeders and the slant-tooth or smoothing harrow. rightly used, destroy countless millions of weeds just as they are fairly born. If not thus destroyed they would steal available moisture and plant food needed by valuable crops and hold it unavailable for plants for a full year at least. The power required to pull up one full-grown ragweed or pigweed would destroy ten thousand of them just when they are germinating. After the corn or the potatoes are up, too, the smoothing harrow or the weeder will destroy the tender, germinating weeds by the million and not harm the larger, more firmly-rooted crops, and will also create a dry-earth mulch. Later the cultivator will do the same deeper.

(5) TILLAGE PERMITS RESEEDING.

Nearly all our crops "run out" after one or more years, and require reseeding (see Chapter VIII). The clovers, except alfalfa, and the grasses except bluegrass, need quite frequent reseeding or are better for it, while the cereals and most of the vegetables are annuals, that is, need seeding or planting every year, and considerable cultivating before and sometimes also after seeding. And even bluegrass, except on the very richest land, is much improved by plowing up and reseeding after a few years in a rotation.

(6) TILLAGE HELPS PREVENT DROUTHS.

This is a matter of observation and is capable of scientific explanation. First, observation. From 1840 to 1870, or a little later, most of the clay soils of the Western Reserve in Ohio were devoted exclusively to dairying with permanent pastures and meadows, never plowed or reseeded. In the dry weather so common in late July and August these pastures and meadows were so closely gnawed and became so dry and baked that, like the Desert of Sahara, the showers did not and seemingly could not fall upon them, and the drouth often became long and terrible. But when tile drainage came with tillage and the growing of corn and other cereals, the very severe drouths ceased to come. The reason was that the cultivated land retained moisture and that this and the abundant existence of the cool, green leaves helped condense the moisture in the air and frequent showers fell, and the long and distressing drouths ceased to afflict the earth. "To him that hath shall be given," even of moisture and rainfall.

(7) FACTS AS TO YIELD.

But more convincing than explanations are some of the facts. For example: It takes three acres of average clay land to pasture a cow half of the year; but one acre of silage on the same land, and with the manure that belongs to it, will feed three cows as long, and with no more mill feed—nine times as much.

CHAPTER XII.

TILLAGE IMPLEMENTS.

The farm boys who read this book know all the principal tillage implements, and it is therefore not necessary to give cuts of them and to describe them in detail as it might be for city high-school boys, but simply to explain briefly the mechanical principles involved, and to call attention to the fact that horse-drawn tillage implements (plow, harrow, cultivator, etc.,) have now almost wholly taken the place of hand tools (spade, hoe, rake, etc.,) for two reasons: First, because horse-power is much cheaper and better than man-power wherever it can be used, and second, because the continuous motion of the horse implements wastes less energy than the interrupted, back-and-forth, up-and-down motion of spade, shovel, hoe, rake, etc. This last is well illustrated in the fact that, and the reason why, the ponderous, old up-and-down saw-mill saw gave way to the large circular saw. The former, with its heavy "head" and frame, must "kill" all its motion or momentum at top and bottom for each cut, actually wasting nearly half of the power required to run the saw; whereas the large buzz saw with its continuous circular motion wastes very little of its required power. So too, though to a less degree, the spade, hoe and hand-rake waste much power as compared with the plow, harrow, etc., with their continuous motion. This seems clear.

Practically all our best tillage implements now have the sliding motion, which gives a polished front to the implement's teeth. The old-fashioned harrow, with big teeth straight up and down, is about the only exception, and is now practically discarded in favor of that with smaller teeth that slant back, usually now at an adjustable angle. This gives the sliding cut which slices the earth and polishes the teeth instead of the dead push of the vertical tooth which simply pokes the earth and does not polish the tooth.

THE PLOW.

The plow cuts the earth with slanting coulter or jointer and plowshare, lifts it with its wedge-like share, cracks, crumbles and partly pulverizes it and inverts it with its curved, screw-like moldboard, and leaves it all ready for harrow, roller and cultivator. The sliding motion on all its surfaces keeps them all polished. It is the pioneer and most thorough and effective of all the tillage implements and prepares the way for all the rest. For completely turning under stubble, clover, weeds and rubbish the jointer or small narrow plow that slices and turns a shallow, narrow furrow a

little ahead of the main furrow, is by far the best thing for turning all such roughage so completely into the bottom of the furrow that they never interfere with the shallower cultivation of other implements.

THE DISK CULTIVATOR.

Next to the plow for thoroughness in inverting and crumbling the soil is the disk cultivator, or the cutaway which is like the disk only the disks are all "cut-away" about three inches deep leaving little "spades" which will dig into hard ground easier than the plain disk. The implement consists of twelve or more sharp, polished steel disks, sixteen or more inches in diameter, fixed firmly on two or more adjustable axles that are set at a converging angle with the line of draft, which makes them turn a dozen small furrows, half to the right and half to the left, completely slicing, pulverizing and inverting the earth. The greater the angle at which the two axles are set, the deeper will the disks dig and the heavier will be the draft. By "lapping half" the ground is kept level. We consider the disk and the cutaway the most helpful inventions in tillage implements yet made since the invention and the perfection of the plow. The double disk for three or four horses is better yet.

BULL-TONGUE CULTIVATORS.

Next to the disk harrow the best and most thorough work in stirring the soil is probably done by the so-called bull-tongue cultivator, with teeth narrow or wide, few or many, for one horse or two or three, for riding or for walking, for broadcast cultivation or for one or two or three rows of corn, potatoes, etc. The bull-tongue teeth slant backward at the top; the slant teeth of the harrow slant back at the bottom; both have the sliding motion which slices the earth and polishes the teeth. The importance of the sliding cut is seen in mowing with a scythe, or cutting leather with a shoe knife, or new bread with a bread knife. If the good wife pushes the knife straight down she will flatten the bread and not cut it. If she gives the knife a sliding motion she can cut it, even when it is soft and hot.

THE ROLLER, CLOD-CRUSHER, ETC.

On lumpy ground these are useful; the former simply crushing and crumbling the lumps, the latter both slicing and crumbling. Neither should be used on clayey land when it is so wet that the lumps will mash rather than crumble. Other tillage implements are simple and their principle of action is easily understood. The spring-tooth harrow is excellent for rough or stony land, for on such land the disk and the cutaway do not work well.

CHAPTER XIII.

ROTATION OF CROPS.

Rotation, as used in agricultural writings, means a circle or cycle including two or three or four different exhaustive crops, each grown for one year, with one recuperative crop sometimes grown two years in the rotation. Sometimes one particular crop, perhaps corn or potatoes or tobacco, seems to pay best under the given circumstances. Then why not grow that best-paying crop year after year continuously? The scientific reasons for rotation are in part as follow:

ROTATION EQUALIZES SOIL EXHAUSTION.

All plants must have the ten "essential elements," and three of the ten or their compounds, nitrogen, phosphoric acid and potash, are liable to run short as we have seen. Crops vary considerably as to the relative amounts of each of the three that they require. For example, tobacco requires about nine times as much potash as wheat and its straw per ton, and thirteen times as much per acre for a good crop. Potash is therefore sometimes called the "predominant requirement" of tobacco, and nitrogen of wheat and corn. Now each plant or crop must have its proper proportion of each element, just as brick and mortar must have the right proportion of lime, sand and water, or you can't lay brick perfectly. Tobacco is known as "a potash crop." Wheat and corn are known as "nitrogen crops."

EXPERIENCE CONFIRMS SCIENCE.

From what has been said it seems clear that if tobacco is grown continuously on the same land, then potash, its "predominant requirement," will soon run short. Now let us see if experience agrees with the teachings of science. For example: Tobacco and potash. The thin hill lands of Brown county, Ohio, and a few near-by counties, grow a fine grade of tobacco, and the farmers would be glad to grow that crop year after year. But they can't. If they clear the hillsides and burn the brush and rubbish they get one fine crop of tobacco. But if they try it again the next year they get a much poorer crop and the third year practically no crop, yet they can get a fine wheat crop after the first crop of tobacco and even after the second attempt. Why? Because the natural potash of the clayey soil, increased by the potash from the ashes of burned brush, etc., gave enough of its "predominant requirement," potash, for one fine crop of tobacco, but not for two or three. But the careful tillage of the tobacco, with the shading of the big leaves, helped the bacteria (already explained) to decompose the humus of the soil and make its inert nitrogen available to supply the "predominant requirement" of the wheat, viz., nitrogen. And so a good crop of wheat ought to and does follow a good crop of tobacco. Then by sowing clover in the wheat and applying some added potash, the clover roots bring up more potash from the deep clay, and nitrogen from the air (as already explained), and the farmers are ready, after a full year with clover, for another year with tobacco and with wheat and clover again in rotation. How simple, when we learn the reason why! In like manner potatoes and cabbages, both strong potash users, both good developers of available nitrogen, are both good crops to prepare for wheat followed by clover. This explains the strongest reason for rotation: it equalizes the exhaustion of plant food.

ROTATION CHECKS WEEDS, INSECTS AND FUNGOUS PESTS.

As to weeds it is perfectly plain that at least one hoed crop in each rotation, if the cultivation is as thorough as it should be (see Chapter XI) will destroy millions upon millions of weed seeds just as they are germinating. As to insects: Wheat after wheat is apt to breed Hessian flies in destructive numbers, because wheat is their natural food. The first crop develops them in small but not destructive numbers. If a second crop of wheat is attempted on the same land the prolific flies are likely to prove, like Mrs. Partington's feelings, "too many" for it. But if clover follows the wheat they perish, for they cannot eat (or suck) the clover. In like manner potatoes after potatoes are likely to be destroyed by bugs or blight; and corn after corn is likely to bring in the corn worm or other corn pests or diseases. But a proper rotation largely prevents these troubles.

SHALLOW AND DEEP FEEDING PLANTS, AND ROTATION.

A rotation is best because some plants are shallow feeders and some are deep feeders. Wheat, and especially the clovers, are deep feeders. Corn and most of the grasses are rather shallow feeders. A proper rotation will draw evenly on the whole three feet and not merely on the top six or eight inches of the soil.

ROTATION DISTRIBUTES THE FARM WORK.

Corn was formerly grown almost exclusively in parts of Illinois, and spring wheat in the Dakotas, and the work was "bunched" into a few months of each year. But crops in a well-planned rotation, fed to cows, beef cattle or sheep and lambs all winter give steady, remunerative work the year round.

ROTATION INCREASES AVAILABLE PLANT FOOD.

This is especially true where clover (a recuperative crop) is

included in the rotation, and it should never fail to be included (see Chapter VIII).

THE ROTHAMSTED EXPERIMENTS.

In the famous Rothamsted (England) experiments, lasting 32 years, with the usual English rotations, namely "roots" (for corn will not ripen there), barley, clover and wheat, each one year, and with all the crops removed and no manure added, and therefore with no plant food used except what was developed from the potential plant food in the soil, under these conditions barley grown continuously averaged only 18 bushels and wheat only 12 bushels per acre; but grown in the rotation with clover, described above, the barley gave 32 bushels per acre and the wheat 26 bushels per acre. That is, the rotation developed more than twice as much available plant food for the wheat, and nearly twice as much for the barley, as did the continuous cropping with each respectively. Good for rotation! That is, facts support the teachings of science. The reasons why clover is so valuable in a rotation have been quite fully explained in Chapter VIII. The above facts about Rothamsted are given and commented on by Professor Vivian in his "Soil Fertility."

CHAPTER XIV.

INCREASING PRODUCTIVENESS.

This can be done in three general ways. 1. By making inert plant food available from soil and air. 2. By keeping on the farm, as far as possible, all the wastes of farming. 3. By bringing to the farm the city wastes and the stored plant food of the past in the form of commercial fertilizers. The first has been fully discussed in Chapters VIII to XII inclusive. The second will be discussed in the present chapter under the general head of Manures. The third will be discussed in one or more future chapters on Commercial Fertilizers.

THE FARM SUPPLY OF MANURE.

In Chapter VIII, under "Exhaustive Crops," as contrasted with "Recuperative Crops" (legumes), it was declared that in general the most exhaustive ones are those that are sold wholly from the farm, like tobacco, flax and vegetables; and the next less exhaustive, those partly sold and partly fed, like wheat; and the least exhaustive ones those that are fed wholly on the farm, like silage, hay, etc. This last is true for the following reasons: Our farm crops, hay, grain, etc., may be roughly said to contain two general kinds of value, their money value (for making meat, eggs, milk and other doubly-organic products, salable as food for men), and their manure value (as food for future plants). And the remarkable and fortunate thing is that our farm animals have the natural but unconscious power of separating these two values, so to speak, that is, of taking the parts or elements which they can themselves utilize in making meat, milk, wool, strength, etc., for man's use, and of leaving all that they cannot thus utilize in their voidings, solid and liquid, as food for future plants. And the fortunate thing as regards maintaining the soil's fertility is that farm animals take on the average (according to most chemists), only about 20 per cent, or one-fifth, of the total essential elements of plant food, viz., of the nitrogen, phosphoric acid and potash, contained in the plants themselves, and reject in their voidings about 80 per cent, or four-fifths of the total, to be returned to the soil as readily available food for future plants. (See Vivian's "Soil Fertility," pages 113, etc.). That is, if intelligently managed and fed, good well-bred farm animals will usually pay us nearly or quite market prices for their feed and bedding, and for the work of their feeding and care as compared with the cost of hauling or sending the crops to market. For if you feed you have to haul to market only 20 per cent of the gross crops fed, whereas if you don't feed you must haul the en-

tire 100 per cent. And if you feed you have about 80 per cent of the plant food to return to the land to keep up its fertility, and if you sell the crops unfed you return nothing to the land. Further than this, the animals make a market for all the farm roughage, grass from rough pastures, corn stover, straw and surplus hay, for most of which but for them we could find no paying market at all. That is why the old proverb is usually true: "It is better to take crops to market on the hoof or in the wool-sack or butter-crock than in the grain bag or hay bale." Of course the wheat, fruits, vegetables must be mostly sold and some corn and hay; but it is fortunate for our farmers that our cities call for and pay for so large a proportion of what may be called "doubly-organic" or animal products.

WHAT GIVES FARM MANURE ITS VALUE?

Chiefly the nitrogen, phosphoric acid and potash contained in it; and these all come from the feed which the animals eat, and of which as already seen the manure contains about 80 per cent if all saved, as it certainly should be always. Of course, as the manure can contain no plant food that was not in the feed, its value will vary considerably with the kind of feed used. Professor Vivian estimates that the total manure from feeding a ton of wheat straw, at usual prices of the elements in commercial fertilizers, would be worth only $1.74; from a ton of corn meal, $4.53; of wheat bran, $9.84; of linseed meal, $15.49, and so on. Now, animals are not fed on any one of these alone but on a fair mixture or combination of timothy and clover hay, silage, mill feed and grain, according to the purpose for which they are fed.

The German chemist Wolff gives the average composition of the mixed liquid and solid manure of horses, cows, sheep and pigs as ordinarily fed, as containing 75.9 per cent water, 0.45 per cent nitrogen, 0.21 per cent phosphoric acid and 0.52 per cent potash. That would give for this manure, probably without bedding or absorbent, in every ton 1,518 pounds of water, 9 pounds of nitrogen, 4.2 pounds phosphoric acid and 10.4 pounds of potash; total 1,541.4 pounds. The rest of the 2,000 pounds, or 458.6 pounds, is chiefly carbon and ash, devoid of valuable plant food. That is, the three essential elements contain all the valuable plant food there is in the ton. You haul and spread 2,000 pounds for the sake of the 23.6 pounds of real plant food, worth, at average prices in fertilizers (before the war), $2.08. The rest including the water is simply "nature's filler." With the usual bedding it is perhaps safe to rate a ton of mixed horse and cow manure, if all is saved, as fairly worth $2, for though the carbonaceous matter is not given a fertilizer value, it is somewhat valuable in loosening the soil to hold more capillary moisture and to make the soil more permeable to roots.

This value should never be forgotten. If commercial manures are used this humus should be got by plowing under clover and other green manure.

VALUE OF MANURE PER YEAR PER ANIMAL.

Cornell University bulletin No. 192, quoted by Professor Vivian, estimates that each 1,000 pounds of live weight, average, of horses, cows, sheep and hogs, young and old, will produce $30 worth of manure if the animals are kept up the year round and fed average feed and all their manure saved. As the average farmer keeps up his livestock only about 200 days in the year it would probably be fair to count the actual value of the stable manure for each 1,000 pounds live weight at $15 or $16 per year, provided all is saved. That dropped on the pastures fertilizes them alone. The great importance of saving it all for the 200 days is therefore apparent. Until quite recently in many sections horses and dairy cows have been wintered on leaky plank floors that wasted practically all the liquid manure, while much of the solid was wasted by leaching under the eaves, or by heating, as horse manure will do if thrown out in large, loose, cone-shaped piles.

RELATIVE VALUE OF LIQUID AND SOLID MANURE.

Many careful chemical analyses and many as careful field and plot experiments have proved conclusively that the urine of our domestic animals is worth as much per year as the dung. And yet until lately, as before remarked, this liquid part has been little esteemed and mostly wasted. At present, in Europe, chiefly because of lack of bedding and absorbent, it is often run into underground tanks or cisterns and pumped up and sprinkled on the land every few days. Our method of absorbing it on cement floors and gutters with straw, chaff, sawdust and the dryer horse manure seems preferable. The point is, to save it all in some way. These facts are repeated and emphasized in the hope that the young farmers who read this book may never forget or neglect the careful saving of all the farm manure.

THE WISE USE OF MANURE.

As to wisely using the manure thus saved, probably the least risk of loss is by drawing it out daily or frequently (with the urine all absorbed) with a manure spreader all fall and winter long and spreading it, not over 10 or 15 tons per acre, as experiments prove most economical, on a clover turf, if possible, that is to be plowed in the spring for corn or potatoes in the rotation. Thus applied there is no waste from heating or fermenting, and little if any from leaching; for on a clover turf rains and melting snows will wash it into the land and not away from it. Further, the hoed crops are the ones that need manure most and can use it to best advantage.

CHAPTER XV.

MAKING, SAVING AND USING FARM MANURE.

LIVESTOCK FARMING.

The practical part of livestock farming "is another story," as Kipling is fond of saying. This book will touch only on the underlying principles of livestock farming. We keep livestock for two objects; first, to get a paying, home, cash market for our grain, grass and roughage; second, to do this and yet retain on the farm about 80 per cent or so of the manure value of these crops, that is, keep up the farm's fertility (see Chapter XIII).

(1) A HOME CASH MARKET.

To do this we must keep the best animals for money-production under our circumstances. Which kind of animals, and which breed or strain of the given kind to keep, will depend chiefly on local circumstances, such as the character of the land, the markets, etc., and partly on individual taste and preference. The entire subject hardly falls within the scope of this book, except to say that beef and pork belong to the richest part of the Corn Belt; dairying, especially the sale of milk, cream and cottage cheese, belongs to farms situated near large cities and manufacturing or mining centers that furnish near and quick market for these perishable products; wool, mutton and early lambs succeed best on farms too hilly and rough for tillage, and for farmers who can furnish little human labor; the egg and poultry business is usually a side issue on large stock farms, or a main business on small farms, with truck and small fruits to supplement.

(2) KEEPING UP THE FARM'S FERTILITY.

It is in place here to discuss how each kind of animals can be best handled to get all the money value, and especially all the manure value out of the feed; that is, to discuss the underlying principles.

SHEEP.

Sheep of the right kinds gain both objects best if fed their hay and grain and silage in winter in racks and troughs, with water tanks accessible, and confined most of the time in large, cool, abundantly ventilated manure-sheds or covered barn yards, with cement or packed and puddled-clay bottom or floor, with plenty of straw, chaff or chopped corn stalks to absorb their urine, which is less in amount and proportion than that of other farm animals.

Their chief product, wool, is very largely nitrogenous, and even the most nitrogenous (protein) feeds available for sheep contain more carbon in proportion than is needed. The excess of carbon creates an excess of animal heat, which together with their heavy, thick wool keeps them too warm for health and comfort unless their quarters are quite open. They need protection from rain, snow and violent wind, but little protection from cold in latitudes from 40 to 45 degrees in this country; less in fact than any other farm animals.

HANDLING THE MANURE OF SHEEP.

The manure thus made will keep unmoved without loss until spring, if desired. The bedding and the small amount of urine and the roof prevent leaching, while the tramping by the sheep excludes the air from the manure and prevents its heating. The tendency is to solidify and cake the manure, and it must therefore be well broken up in loading into the spreader, so that the latter may spread it fine. The spreader will abundantly pay its cost for the manure of 25 or less cows and horses or 250 or less sheep thus kept. It will do the work of ten men and do it far better and cheaper. Horse power is cheaper than man power, see Chapters XVIII and XIX. Exercise daily in good weather in yard or pasture is good for the sheep.

FATTENING CATTLE.

These should have rather open, well-ventilated sheds, as their feed is largely corn, a heat-producer. If dehorned the cattle may be kept unconfined, and handled much like sheep. With plenty of bedding their manure may be handled similarly. If fed corn stover in part and the refuse used for bedding, the stover should be shredded or cut to save food waste and to prevent profanity in pitching the manure, and to fit the latter to be evenly spread by the spreader. Full-length corn stalks in manure are an abomination.

POULTRY.

Laying hens and pullets in order to be made to lay well in winter, as they always should, must have warm and yet well-ventilated quarters. If their combs are frosted, even once, laying will probably cease and serious loss result. To prevent this their houses should have floors, sides and shed-roof double, with air space between, and have glass (or at least muslin) windows occupying the upper half of the southward front. To save the manure best the roosting-frames of poles or slats, the entire length of the rear, should be at least 15 inches above a tight, smooth board platform, itself 40 to 48 inches from the floor and well sprinkled with dry sawdust or road dust (never with lime, for that will liberate and waste nitrogen) to catch and to absorb the moisture of the

droppings. It is well to have the roosting-frames hinged in the rear and swung and hooked up against the roof by day, both to facilitate the daily cleaning of the manure platforms and to prevent lazy hens from roosting by day when they should be laying eggs or scratching on the littered floor for feed and grit and for

An Up-to-Date Poultry House Where the Manure Is Saved.

exercise and warmth. The manure thus saved, as well as that from an occasional cleaning of the cement floor itself, is the richest of all farm manures.

MANURE FROM PIGS.

Pigs should be fed in winter in covered sheds or pens with cement floors well littered with chaff or sawdust, the floors cleaned often and the refuse mixed with cow or horse manure or kept in a tight pit till used. It has more liquid than any other kind of farm manure.

MANURE FROM THE DAIRY.

It is the writer's opinion that most of the hilly and rolling farms, whose owners and their sons will read this book, can be made to bring more net income and keep up fertility better under dairying, perhaps with poultry and a few pigs, than under the production of meat or wool. Also that with the rapid increase of our city and village population dairying will become increasingly profitable. When our population becomes as dense as it now is in many European countries we shall be forced to eat far less meat

and more dairy products, cereals, vegetables and fruits, because these will support a larger population to the acre or the square mile, as already shown.

NET INCOME AND INCREASED PRODUCTIVENESS.

Both of these favor and are promoted by dairying on our rolling and hilly lands where this book will be most read. And so I feel justified in giving more thought and more space to the dairy and its management than to any other lines of livestock farming; partly also because dairy farming seems more intricate and difficult than the others, unless it be the breeding of pure-bred sheep, horses, etc.

CHAPTER XVI.

THE DAIRY BARN.

This is of such prime importance that I give considerable space to the discussion of its principal points. In the past 50 years I have made a careful study of dairy barns, visiting hundreds of the best ones in the principal dairy regions of the United States and Europe, and shall endeavor to give here some of what seem to me to be the best features of all.

THE SHAPE.

Both for economy of construction and in handling the animals and their water, feed and manure, the best form is brick shape, or rectangular, say 40x60 or 80 or even longer on the ground and 20 feet high to the eaves above the basement, and with ordinary single-slope quarter-pitch roof. This shape is cheaper than the octagon and this roof is cheaper than the gambrel roof, and to my eye looks better. Forty feet is about the extreme width at which the roof can be made strong enough for heavy snows, by using a single purline plate on each side. If much wider there must be two purline plates on each side and that feature will be found to increase the cost more than proportionately. The length, however, may be increased to 100 feet or more, and will increase the expense less than proportionately because it does not increase the siding and timbers of the ends at all, only of the lengthened sides.

THE HEIGHT.

Roof and foundation are the expensive parts, therefore put as much between the two as gravity will permit. For basement 8 to 10 feet is best; for height above the basement to the eaves 20 feet is enough for hay and grain if the silo is used, as it always should be on a dairy farm. And if horse fork is used for the hay the storage is not hard. If considerable wheat and oats are grown, as they should be to help net income and to furnish abundant chaff and straw for bedding, this grain in bundles had best be stored for threshing close to the main or threshing floor, on each side of it, and the straw or the second crop hay be stored there after threshing.

A GROUND-LEVEL BASEMENT.

For light, ventilation and health the dairy barn had best be on slightly sloping or nearly level ground, with a "made" bank or approach to the barn floor or floors, the approaches walled up some 12 feet from and parallel with the barn front, and bridged to the floors with reinforced concrete. This makes a roof of a good shed for milk wagon, etc. In the approach or bank can be made a long and rather narrow and shallow cistern with arched top for strength, and connected under the stables with two-inch galvanized pipe, to take the water from the entire barn roof. The cistern in the bank of the writer's farm barn holds 360 barrels and furnishes enough water for 25 head of cows and horses and some "young things," since the normal rainfall on the roof will fill it 12 times in a year.

THE BARN FRAME.

By far the cheapest and best barn frame is of scantling, spiked together, and not the old-fashioned heavy timbered mortise-and-tenon frame. That form of frame was discarded for houses over 60 years ago in favor of the scantling frame. It should be discarded for barns also. The scantling frame saves fully one-third the cost of timber and more than three-quarters of the cost of framing and raising. The "bents" of the writer's barn shown in the photo-engraving on this page were spiked together, complete and all ready to raise, in three days by four carpenters and raised as shown in the picture, by 20 neighbors in four hours. A neighbor's barn, about the same size, 40x80 feet but with old, heavy oak, mortise-and-tenon style frame, built the same summer, took eight carpenters three weeks to frame it and 80 neighbors eight hours to raise it. The six inner bents of the writer's barn (see picture) have no cross-beams or girts, but form an unobstructed truss-arch clear to the top and the whole length of the barn for horse fork and hay carrier.

W. I. Chamberlain's Shawver or Scantling Frame for Barn.

SIZE AND INSIDE ARRANGEMENT.

For 25 cows, four horses, a bull, and a few calves and heifers 40x80 or 82 feet is a good size. This gives a 15-foot double feed

way through the middle with stanchions on the south side of the feed-ways for 25 cows, and stalls for horses and stanchions and pens for heifers and calves and bull on the north side. It is best to put cows on the south side where they will get more sunshine. At least the upper four feet on both the north and the south sides should be nearly all windows, double or double-glazed with air-space between the glass, for warmth and to prevent the breath from the animals freezing on the inside of the glass. The inside windows should be hinged at the bottom (part of them at least) and let back on a stay-chain at the top for extra ventilation when desired in mild weather. Thus hung, the wind will not reach the cows' backs.

EXTRA VENTILATION.

But, aside from the above described ventilation for mild weather, there should be in every dairy barn the so-called "King system" of permanent or cold-weather ventilation as follows: Two flues on each side of the barn running to the open air above the eaves, or to the eaves inside and then between rafters inside to the gable ventilators or cupolas, with screened entrance near the stable floor to "suck" out all the foul, heavy, carbonic acid-laden air from the animals' breathing and from the manure. Also four screened entrances for fresh air near the flues and near the top of the stable to admit fresh air from the outside. The suction in the first-mentioned flues is strong.

SILOS AND MANURE SHED.

The silo or silos can be at one end of the feed passage with track-carrier or big two-handled, two-wheeled bins with one small guard-wheel before and one behind, to receive the silage directly from the silo and carry or wheel it in front of the animals for distribution in their deep, tight cement mangers.

SAVING AND USING MANURE.

As to saving all manure, there should be cement or cork-brick floor under the cows, and the latter or wood-block or plank floor under the horses, with cement manure "drop" or gutter for the cows 4 to 6 inches deep and 20 inches wide, and just far enough back from the stanchions so that the cows can lie down or stand with perfect comfort on their bedded platform and all their voidings drop into the manure gutter. Also there should be a walk three or four feet wide behind the gutter along under the windows. The gutter should be cleaned out each morning and the manure spread with spreader (if weather permits) on clover turf that is to be plowed in the spring for corn or potatoes as before described. Thus saved and spread there will be practically no waste. The corn will be best where the manure was spread earliest, because the manure has soaked in the most fully there. From 10 to 15 tons of such manure per acre is on the whole most economical, as has been shown by careful experiments, on fairly good land. This rather light dressing together with 200 to 300 pounds per acre of 16 per cent acid phosphate on the wheat seeded to clover, in each four-year rotation, is enough to give a rapid increase of productiveness and of total plant food to the land.

MIXING THE MANURE IN THE DROP.

It is better to have the cows out in the sunny barn yard on fine days, or in the well-littered covered barn yard or manure shed in bad weather, while their stables are being cleaned out and re-bedded. Then if the stables and end doors are rightly arranged the manure spreader may be driven through the stable and loaded directly, with only one handling by human muscle. Or a manure carrier hung on rollers on a track in the rear of the gutter can take the manure outside or into the manure shed at the end of the stable and dump it into the spreader; or, in bad weather, into a compact pile to be drawn and spread later with the spreader in good weather. As soon as the manure is all out each morning, it is well to sprinkle from two to four pounds of 16 per cent acid phosphate per cow per day, into the drop to help absorb the urine and prevent loss of ammonia. None of it will be lost, and it will help to balance the excess of ammonia (nitrogen). Also spread along in the drop all the dryer, more strawy horse manure, which is likely to heat and waste ammonia if thrown out in a pile by itself. Mixed with the colder, wetter cow manure it gives a better texture, temperature and moisture to the whole. In addition to this shake into the drop enough of the soiled straw and chaff from the heavy bedding on the cow's platform between the stanchions and the drop to make sure to absorb a day's liquid manure, so that it can be handled with a six-tined manure fork. Some sawdust will help. In some parts of Europe, where bedding is scarce, the liquid is run into manure-cisterns, as already stated, and once a week or more is pumped into a great sprinkler and sprinkled by horses or oxen upon the land; but it is a nasty job, as the writer can testify from seeing and smelling the work. Our American way is better even if we have to use (worthless) sawdust or planer shavings in part for absorbent. Chaff and chaffed straw are much better, however, for most of the bedding, for they have a manure value in themselves of about $2.25 per ton if thus used, besides their great value in absorbing the urine and in adding humus to the soil. Also every dairy farm should raise wheat and oats enough to increase the net income by sale of grain and to furnish abundant bedding and absorbent. Oat straw and even bright wheat straw fed in the mangers or yard or manure shed will give considerable roughage feed, and the refuse may be used for bedding.

CHAPTER XVII.

COMMERCIAL FERTILIZERS.

INCREASING FERTILITY BY COMMERCIAL FERTILIZERS.

By the two methods or means already explained, viz., (1) rendering inert plant food available, especially by tiling, tillage, rotation and clover, and (2) feeding good livestock and saving and wisely using all farm manures, the productiveness of a farm may be fully maintained. But (3) by using commercial fertilizers in addition the productiveness can, if desired, be quite rapidly increased. For commercial fertilizers actually bring to the farm added or outside plant food, and the more you can buy profitably the faster you can increase your crops and your present and future fertility and net income.

WHAT ARE COMMERCIAL FERTILIZERS?

Simply greatly condensed plant food in available form or condition, usually sold in sacks. Their sources and composition will be explained further on. Considerable prejudice has existed against them, and you will sometimes, even yet, hear men say they are "mere stimulants," "whiskey, not food," and that, after the "stimulus," exhaustion will come to the land as to the drunken man after a debauch. Is this true?

ACTUAL PLANT FOOD MUCH CONDENSED.

No, it is not true. Commercial fertilizers as sold now under state law, with guaranteed analysis on each sack or package, with heavy penalty for false guaranty, contain certain percentages (amounts) of one or more of the three essential elements of plant food, in greatly condensed form. A high-grade complete fertilizer with a 4-10-5 analysis, contains about nine times as much nitrogen and potash (each) and over 47 times as much phosphoric acid as a ton of mixed stable manure (see Chapter XIV). Further, the proportions are far better, far closer to the "predominant requirements" of most soils and plants. Thus it is true that fertilizers (commercial) contain the same kind of plant food contained in stable manure but in a very condensed form.

Condensation is an advantage partly because it saves freight, and because it saves labor in applying. This needs no explaining, for it is about twenty times as light on the average for a given amount of plant food, and it costs practically nothing to apply it with the grain drill, while drilling in the grain, but to apply an equal value of plant food in manure, say 20 tons, would cost $5 to $10.

We condense maple sap or "sugar water" 40 to 1 to get the delicious maple syrup for our buckwheat cakes, and we condense milk not quite so much to fit it to be sent in cans all over the world where the bulky and perishable milk uncondensed cannot go. And so with many other foods and medicines. Anthracite coal is condensed wood or carbon, and we do not object to using it. Why then should we object to condensed fertilizers? It is simply an ignorant and foolish prejudice.

THE PRINCIPAL SOURCES OF FERTILIZERS.

Hereafter in this book the single word "fertilizers" will be used for commercial fertilizers and the single word "manures" for farm or stable manures. The principal carriers or containers of plant food in fertilizers are, (1) the saved wastes of modern life and (2) the vast natural deposits of past ages. (1) The saved wastes of modern life include (a) the saved refuse of slaughter houses, the food wastes of the cities, and the city animals that die, (b) the nitrogen saved from coke and gas making. When farmers butcher hogs, etc., they usually waste the blood and most of the leg and head bones, and the entrails, etc. The city slaughter houses save all these wastes and the fertilizer men gather up the bones from butcher shops, the best of the garbage from the homes and the city animals that die, and reduce their rich stores of plant food, dried, treated chemically and deodorized, and sell it as fertilizers. In the slaughter houses every drop of blood is saved by means of tight floors and gutters, and it is dried and contains 12 per cent or more of nitrogen worth 12 to 15 cents per pound. The hogs' heads after the available meat is cut off for head cheese, sausages, etc., and some of the other bony parts after they have been thus treated, are all steamed in huge tanks and the fat rises to the top and is saved. The smaller, crumbling bones and cooked lean meat and tendons are dried and ground into "tankage" which contains 4 to 9 per cent of nitrogen and 3 to 12 per cent of phosphoric acid, depending on the proportion of meat and bone. The feet of cattle make neats-foot oil and glue, and the refuse makes hoof meal, rich in nitrogen. The horns of cattle are made into combs, buttons, etc., and the shavings and scraps make horn meal, rich in nitrogen but needing treatment with sulphuric acid to make it readily available. The larger bones, shin bones, etc., of cattle are cut into "ivory" handles for tooth brushes and knives, etc., and the wastes in cutting, together with the bones from the tanks are ground into bone meal, containing 1 to 4 per cent of nitrogen and 20 to 30 per cent of phosphoric acid, according to the degree of the steaming. Dead horses have their hides, soap-fat and glue saved and the rest goes into bone meal and tankage or meat meal, all rich in plant food. Thus in general are the wastes saved.

NITROGEN FROM COKE MAKING.

Coke is made from "soft" or bituminous coal, and this coal being of vegetable or wood origin still retains some of its original nitrogen. In coke burning all this nitrogen has in this country until lately gone off into the air, a waste. Recently over some of the coke ovens hoods or retorts have been placed to separate and save the nitrogen. The process of saving it is found to be practical and profitable, and it is roughly estimated that if all were saved from the manufacture of coke and gas it would supply about as much nitrogen as is now used and sold in fertilizers. Recently also nitrogen has been separated from its vast mixture in the air, by chemical means, and made available in agriculture and for gunpowder.

PREHISTORIC SOURCES OF PHOSPHORIC ACID.

We have already spoken of the bones of our present or recent animals as one source of phosphoric acid. But a larger and apparently inexhaustible source is found in the so-called phosphatic rock found in vast beds or deposits in Tennessee, the Carolinas and Florida and lately in the Samoan and Alaskan islands. These beds or deposits (except the Samoan which are largely coral and the Alaskan which are recent) seem to be mainly made up of the bones of prehistoric land and sea animals, swept together apparently by sea tides and currents during the ages when a vast arm of the sea covered most of the land east of the Mississippi River from the present Gulf of Mexico nearly to the Great Lakes, advancing and retiring with the slow subsidences and upheavals that occurred while the "coal measures" were slowly forming. The geologists explain how this all took place. It is perhaps sufficient for our present purposes to say that these vast deposits of phosphatic rock now actually exist; that they seem mostly made up of the fossilized bones of prehistoric animals whose flesh and the nitrogen of their bones have perished. The proof is that teeth and larger bones of such animals are abundant and clearly seen in such rock, as the present writer can testify from the sight of his eyes and the touch of his fingers. Such rock contains from 20 to 34 per cent of phosphoric acid, according to locality, depth, impurities, etc., but no nitrogen, that element having been lost in the fossilizing or petrifying process, and the phosphoric acid being far less available as plant food than that in the finely ground bones of modern animals, even when the former is ground into the finest "floats;" so that the former has to be treated with sulphuric acid (cooked, so to speak) to make its plant food readily available. Canada "apatite," a natural rock, and "Thomas slag" a by-product containing the phosphorus taken from iron ore in smelting (because injurious to iron), are not much used in the United States, because their phosphoric acid costs more here than that from bone or phosphatic rock, which is found here in abundance.

NATURAL DEPOSITS OF NITROGEN.

The principal ones are the nitrate of soda and guano. The former is found in large quantities in the rainless regions of Chili, and is called Chili saltpeter. The refined product which we get here looks like coarse, yellowish common salt, and is as soluble as common salt, and hence liable to waste unless used on crops whose roots can soon utilize it. Chili supplies about a million tons of it for agriculture, besides much furnished for gunpowder. Guano is chiefly found on the nearly rainless islands off the coast of Peru. It consists chiefly of the dried voidings of fish-eating birds and is therefore rich in available nitrogen and has considerable phosphoric acid. I saw hundreds of tons of it in a huge pile in a fertilizer factory in Holland in 1911. Its ammonia was escaping so as to bring tears and partial suffocation to one in passing through the great room where the pile lay. Packed solid at its source on the dry islands it does not waste, but handling it admits the moist air and to prevent waste it must be soon used in manufacturing combinations changing it to sulphate of ammonia, which stops the waste. That now used is not an ancient deposit. The manager of the Holland factory said that a Dutch syndicate now owns most of the islands and protects the birds and cleans and ships their voidings, scraping clear down to the bare rocks every three years, when it has reached a depth of about three feet.

PREHISTORIC DEPOSITS OF POTASH.

About the time our forests were all cleared for agriculture, and wood-burning practically ceased in the United States because coal became a cheaper fuel, and therefore potash could no longer be made to any extent as formerly from wood ashes; and at the same time the value of potash as plant food on certain soils and for certain crops began to be demonstrated—just about this time, some 50 to 60 years ago, vast prehistoric beds of potash were, as by chance, discovered in the region of Stassfurt, Germany. Men were drilling deep to find rock salt and drilled into certain acrid impurities which spoiled the salt as salt. In their disappointment they investigated further and found that the "impurities" were chiefly potash, which has almost ever since been worth (when recrystallized) from 3 to 5 cents per pound, whereas common salt (which they were seeking) is worth less than half a cent per pound! Soon deep mines were opened and the manufacture of condensed potash salts began on a large scale. The best and cheapest present form as plant food is the sulphate of potash, made by combining it with sulphuric acid. It looks much like common salt, dissolves about as readily, and contains about 50 per cent of actual, available potash. The muriate, (a recrystallized combination with muriatic acid) contains about the same per cent of potash, but in a combination ap-

parently somewhat injurious or at least less beneficial to potash-requiring crops like tobacco, potatoes, etc.

THE ORIGIN OF THE POTASH DEPOSITS.

Of course the geologists wanted to account for these vast deposits. Their present well-established belief is, briefly stated, as follows: Ages ago a large inland salt lake extended over the wide region between the Hartz Mountains and the sea, connected with the sea by a shallow, narrow channel. This channel admitted the sea water, specially rich in potash then and there, as fast as the heat of the then still cooling earth and air evaporated it. Finally this lake was slowly filled with potash salts, more or less impure, and with common rock salt and the channel was filled and the entire deposits were covered with a crust or roof of earth and rock. And the whole was left for ages, to be discovered like the world's supply of coal just when mankind had come to need it and to know how to use it. These deposits extend over a large region, and scores of shafts have been sunk, some of them nearly a mile deep, and mines opened all over that region. In 1911 a small party of agricultural teachers and writers from the United States descended deep into one of these mines and studied it and the vast re-crystallization plant or factory at the surface. We found it one of the most remarkable and interesting things agriculturally that we saw in all our European travels. There seems enough of the potash to meet the wants of agriculture, manufactures and commerce for ages yet to come.

Such are some of the main sources of our fertilizers. Surely this earth is well stored, along this as well as other lines, with all the materials and supplied with all the forces that man will ever need. Why should we not freely use these vast deposits of plant food stored in the past for our present agriculture, just as we use the equally vast deposits of salt, natural gas, coal, lime, building stone, iron, copper, etc.? Why should we be prejudiced against one more than against any of the rest?

This however is true: commercial fertilizers are so condensed that they contain no humus, and humus is necessary to loosen and darken the soil. If these fertilizers are used we must supply the necessary humus by stable manures with their bedding and absorbents, or by growing clover, cow peas or other enriching crops in every rotation, and plowing under at least their second crops and the manure made from them, or by both of these means.

CHAPTER XVIII.

HOW AND WHEN AND WHAT TO BUY IN FERTILIZERS.

You will hear men say, "I don't want any rock goods." Here once for all let it be said the source is not important. Nitrogen is nitrogen, the same element identically, (and the same is true of the other essential elements) whether from vegetable origin as in linseed or cottonseed meal or from animal origin as from guano or blood, meat and bone, or city and slaughter-house wastes, or from mineral origin as from the wastes of coke burning, etc., or the phosphorus from phosphatic rock or apatite, or the potash from rock salts, or the nitrogen from Chili nitrates, or what not. The only questions of importance are whether the price is fair and whether in the given fertilizer it is in a readily available condition and not subject to waste; and that is for the manufacturers to guarantee, and for the state chemists to enforce under our excellent laws on the subject, with publicity and penalties.

IS IT WISE TO BUY FERTILIZERS AT ALL?

Yes, but to supplement and not to supplant tiling, tillage, rotation, clover and manures. These will maintain productiveness; but the good farmer wants to increase it. The average yield of wheat and corn in Ohio and near-by states in the past has been only about 16 and 35 bushels per acre respectively. By using fertilizers wisely and freely in addition to the above-mentioned means of maintaining productiveness, the enterprising farmer may at an increasing net profit, year by year, soon increase his average to 30 bushels per acre of wheat and 60 or 70 of corn, as many farmers have already done. Why not? Further, the city and slaughter-house wastes got all their plant food from the farm and surely it should be returned to it as far as possible. Also it is surely as wise to use plant food stored up for us in the past as it is to use the coal, iron, building stone, etc.

WHICH FERTILIZER ELEMENTS TO BUY.

Soils that will regularly grow good clover in rotation, and especially tile-drained and all deep, black soils that produce rank, green-colored corn, oats, etc., do not usually need purchased nitrogen. The farm manures, always relatively over-rich in nitrogen, with the clover roots and often the second crop plowed under, give plenty of it relatively and it is not wise to pay 15 or 18 cents per pound for that expensive element. Again, most of our good clayey loam soils hold in the first foot of their depth enough inert potash

for a thousand crops or more, and still more in the subsoil. It simply needs to be developed and made available by some of the means described in preceeding chapters and perhaps by applying lime to increase the rankness of clover, alfalfa, etc., whose roots will bring available potash from soil and subsoil. But sandy soils, and especially muck soils, are unusually greatly helped by potash. On some of our muck soils a single heavy application of potash has been known to increase the yield of sound corn from nothing up to 50 bushels per acre. Also "potash crops," (tobacco, potatoes, tomatoes, etc.) especially on sandy soils are greatly benefited by its use. Just now because of the war in Europe potash cannot be had to any extent at any price.

PHOSPHORIC ACID ALMOST ALWAYS NEEDED.

Finally, nearly all soils and crops seem to need and to be greatly helped by the use of available phosphoric acid. The sales of grain, hay, milk, cheese and livestock from the farm make a heavier drain proportionately on this element than on either of the other two. And so on my own farm for several years I have found it pays best to buy good superphosphate. It happens that lime has never done any good on my farm on any crop, as proved by repeated and careful experiments. Clover does well regularly as all the plow land is tiled.

PROTEIN FEEDS FOR NITROGEN.

It may be well to remark in passing that aside from clover-growing, the cheapest source of nitrogen is found in the so-called "protein feeds," wheat-bran, oilmeal and cottonseed meal and gluten (protein) meal, distillers' grains, etc., which are all very rich in nitrogen and which pay their cost as feeds for "young things" and dairy cows, and leave nearly 80 per cent of their plant-food value in the animal voidings if properly saved and used. In a certain sense the animals "eat their cake and keep it too."

HOME-MIXED FERTILIZERS.

Shall we buy the needed elements and "mix them with shovel and sieve on the barn floor," as advised by some? I think not. In the first place if we buy only phosphoric acid there is no mixing to be done. Second, most farmers have not the necessary chemical knowledge, as most of the station men have. Third, human muscle with shovel and sieve cannot compete either in cost or thoroughness with steam power and with machinery specially adapted to perfect pulverizing and mixing and cheap sacking (see Chapters XIX and XX, to follow). These and other reasons make me feel quite sure that the average individual farmer cannot afford to mix his own fertilizers. If a grange or company of farmers with some one of their

number who has sufficient chemical knowledge will buy for cash in one or more car-load lots, it may pay; but even then the profit or saving will lie mainly in cash versus credit, wholesale versus retail, and in thus cutting out one middle man; all of which can be done just as well without home-mixing. If any manufacturers now charge too much for machine-mixing, free competition will soon bring down the price to the level of supply and demand, as in other things. Let us emphasize the fact that the individual farmer cannot secure the minute fineness and perfect mixing necessary to reach every particle of the soil when only 200 or 300 pounds per acre of the fertilizer is used, unless he has a good grinding and mixing mill run by some cheaper power than human muscle, (see Chapters XIX and XX). Further, tankage or some other "containers" or "carriers" of nitrogen really require chemical treatment as well as perfect mechanical-mixing to make the nitrogen readily available and yet not subject to waste; and the farmer has neither the means nor the special knowledge required for chemical treatment. This is an age of special knowledge, special power-machinery and of finished products all ready for use. "The stars in their courses" and the mighty forces of nature seem against home-mixing.

CHAPTER XIX.

FARM POWER AND FARM WORK.

A FEW DEFINITIONS.

In this chapter and a few that will follow the words "power," "force," "strength," "energy," "work" and any of their synonyms will be used in their older and more general and popular meanings, which are still sanctioned by the Century and other great dictionaries, rather than in the narrower, special, technical meanings given them in recent books on physics. For example: we use "power" to mean that which can do "work," and since "there is no work without motion," power is that which can move or change the motion, shape or character of any matter. "Strength" of men, animals, etc., is the ability to exert power or force. Strength of materials, such as iron, timber, leather, etc., is the ability to resist any power or force that tries to bend, break, stretch, tear, twist or crush the given material. "Work" subjectively or actively is the actual exercise of power. "Work" objectively or passively is the thing done or to be done by power, as when we say a man is looking for work. "Force" is the exercise of "power" on matter. "Energy" as commonly used has a broader meaning than "power," and includes mechanical power as well as heat, light and electrical energy. To illustrate: in the formerly inaccessible gorge just above the Big Falls in the Cuyahoga River in Ohio, a dam about 69 feet high just above a fall of about 25 feet and rapids of some 25 feet vertical in a half mile, gives a total vertical fall of 119 feet; and great turbine wheels, dynamos, etc., convert this great water and electrical power into electrical energy which, supplemented in low water by steam power and always conveyed by cables, lights a city and several villages, toasts bread, cooks buckwheats and heats flat-irons in many homes, propels, warms and lights many city and suburban cars, runs milking machines and other machines in several barns, and does many other similar curious and diverse things. Now we have learned to think of all these things as forms of electrical energy, but we hesitate to call light and heat forms of power, especially of water power. The doctrine of "the correlation, conservation and persistence of energy" explains it all. Just as no matter is ever annihilated or destroyed, so no energy is ever lost, though its form of manifestation is changed.

FORMS OF FARM POWER.

For doing farm work we may mention seven kinds or forms or sources of power, energy or force. As an ultimate source they all depend upon the sun's energy, as we shall see further on. We should use the cheapest, all things considered. They are here named in the order of their cheapness or least cost in proportion to the equipment required and to the work done; as follows: 1, gravity, 2, water power, 3, wind power, 4, gasoline power, 5, steam power, 6, muscular power of animals, 7, muscular power of men. Electrical energy is not so much a power as a means of transferring, distributing, and applying the power of water, steam and gasoline, etc. All of these kinds of power depend as remarked already, directly or indirectly upon the energy of the sun; for even gravity in most cases depends upon the sun for its means of working or its chance to work as will be shown further on.

1. GRAVITY.

Gravitation is the wider word. Celestial gravitation is the force that holds planets and stars in their orbits. Terrestrial gravitation, commonly called simply "gravity," is that mysterious, silent, unseen force which unceasingly draws all bodies towards the center of the earth (straight downward) and gives them their weight in proportion to their actual mass. Indeed the word gravity is sometimes used for weight as also is mass. Gravity is the force that holds great buildings solid to the earth and together with friction, adhesion and cohesion prevents their blowing away. Together with friction also it enables horses to draw the plow and men to walk. Gravity is always ready to work for us if we will but give it tools, harness, means for work. For example: if we put our maple syrup boiling-place on a sufficient slope, gravity will run the sap or sugar water from the gathering tank on the stone-boat sled down through the storage tank and back and forth and onward through the channels of the evaporator until it runs out as finished syrup at the further end, without a cent's cost or a pound's work of dipping or lifting by human muscle. On one farm in Summit county, Ohio, two large maple orchards, a mile apart, have their sap gathered, run into large tanks near by and piped by gravity to the boiling place on lower land near a brook, half way between, at no cost but for the inch galvanized iron pipe, and with a saving of time and horse flesh of two half-mile boat-sled hauls on bare ground.

Countless homes in Vermont and other hilly regions have running water free at house and barn from a spring higher up on the hillside, because gravity works for nothing after the pipe is laid.

If your bank barn is on a gentle slope you can easily, by horse power, using those mechanical powers, the inclined plane, the wheel and axle and the pulley, store hay and straw in the mows, and with steam power blow the silage into the tall silo all in a few days, and then all winter long will gravity at not a cent of cost take these feeds down to the cows and horses in the well-lighted and ventilated basement; and the water from the big cistern filled all sum-

mer and winter by the rains on the roof; and all without a pound of lifting or pumping, if all is arranged so that the ever-willing force of gravity can work.

With proper garret tanks and proper pipe connections, gravity will store the roof water in the garret and send it down through the basement furnace, and by pressure send it up again, giving hot and cold soft water in every sink, bath, lavatory and water closet, with no cost except for equipment. These are some of the things that gravity stands ever ready to do for us. Why do not more of us farmers furnish the necessary equipment? We know whereof we speak, for our own sugar-house, bank barn and house water and storing systems were equipped practically as described above. But gravity is limited to such uses and cannot be utilized as a motive power for other general farm or machine work.

2. WATER POWER A MEANS OF USING GRAVITY.

The water wheel is really simply a way of using falling water as a tool or harness for gravity. Wherever a stream has fall enough so that a dam can give a vertical fall at reasonable proportionate cost, an undershot, overshot or turbine wheel will give the next cheapest form of farm power. Near our home are two farms through each of which runs a large brook or small creek with fairly good fall. Each creek has been dammed and with turbine wheel, dynamo, storage battery and necessary equipment, gives electric light for house and barn, heat for ironing and for cooking buckwheats and toasting bread at the table, and light mechanical work such as separating cream, churning, running milking machine, etc. Thousands of little streams with heavy fall all over our hilly regions might easily be similarly utilized. Since we have learned to harness electricity and teach and compel it to transfer and distribute the energy of falling water, many of the larger and hitherto inaccessible water-falls are being utilized to do work like that described just above as being done by the Big Falls of the Cuyahoga River. Niagara Falls is doing such work on a vast scale and using only a small part of its vast power. The large rivers of hilly New England with their branches have an average fall of nearly 1,000 feet from their sources on the hills to the Sound or the Sea, and directly or with electricity as a means, nearly every foot-pound of the energy of their falling waters is made to pay tribute; and its rivers are becoming more and more the chief source of New England's wealth. But water power, even using electrical energy as a means, is possible only on a small percentage of our farms.

3. WIND POWER.

Next in cheapness on the farm is wind power. Like that of gravity the power itself of wind costs nothing. Unlike gravity it is not at all constant but quite fitful in its willingness to serve us. In level, windy Holland, where there is little water power and little coal for steam power, and where the wind is far stronger and more constant than here, wind is much used in pumping surplus water from lower drainage ditches to larger, higher-level canals, whence it will flow into the sea. Also in Holland, and in Denmark especially, wind power is much used in grinding grain and in doing many other kinds of stationary farm and dairy machine work. In Denmark and Holland we saw many huge windmills; one in particular we visited in Denmark whose immense fan-arms some 30 or 40 feet long each way from the center gave it the power of 60 horses, in a fairly strong wind, as we were told. It grinds the grain and does other community work that can be brought to it, for quite a large population —mostly farmers. In Ohio and near-by states wind is used chiefly for pumping water, but we are not at all sure of wind when we want it. This lack, however, can be overcome so far as water-pumping for livestock is concerned by having large elevated storage tanks and gravity pressure; so far as milking machines, separators and churns and lighting house and barn, etc., in dairy regions are concerned, by having large storage batteries, dynamos, etc., and converting wind power into electrical energy. But the windmill and its work are strictly stationary, that is, the work to be done must be brought to or near the power, except when used as electricity.

4. GASOLINE FOR FARM WORK.

Next cheapest, probably, in proportion to the work it can do and better in many respects, is the gasoline engine. Unlike gravity, water and wind, it is movable (not stationary), and to some extent can go to and along with the work to be done, as in the automobile for travel and transportation, and the tractor plow, harrow, etc., for cultivating, already being made quite practical on fairly level farms. Unlike the three other powers or forces mentioned, gasoline power itself costs money, and to harness and equip it costs, on the whole, more than in the case of the other three. For its source of power or energy, gasoline costs labor in drilling for and in pumping the crude oil, and in separating and refining the more inflammable gasoline. But it does the lighter stationary work of the farm, including pumping, fodder-cutting, running the separator, churn and milking machine, furnishing electrical energy of all kinds, through storage battery and needed equipment, nearly as cheaply, all things considered, as wind and water power, and it can be had on every farm, unlike water power, and at any and all times, unlike both is a movable power and becoming more so every year. It is a very great benefit to the farmer.

5. STEAM POWER IN FARMING.

Next higher in cost is the steam engine, chiefly of the traction kind so as to take itself from farm to farm for very heavy stationary work like threshing grain, baling hay, cutting silage and blowing it into silos, wood and lumber sawing, etc. But for the movable work of the farm, including road travel, it cannot at all compete with gasoline. Its fuel, non-organic, coal, is fully as cheap as the non-organic fuel gasoline; but its serious handicap is the great weight of the engine and of its needed fuel and water as compared with the weight of the gasoline or automobile engine and its needed fuel and water. And for farm work it is quite out of the race compared with gasoline except for heavy, stationary work of the kinds mentioned where the power stands still to do its work, and the work is or has previously been brought to the power.

CHAPTER XX.

ANIMAL POWER.

Next more expensive, (and much more so) is the power of farm animals, horses, mules and oxen for plowing, cultivating, hauling, traveling and all the movable work where the power must go to or constantly move along with the work to be done.

REASONS WHY STEAM IS CHEAPER THAN MUSCLE.

For most of these kinds of work nothing, except possibly gasoline, as noticed above, seems as yet able to compete with animal muscle. But for foot-pound or ton-mile of heavy work, animals cannot at all compete in cost with gasoline or steam for any kinds of work that either of these two is adapted to doing. The reasons for this are several and they are well worth considering, in part as follow: First, the energy-giving fuel (food) of animals is very much more costly per foot-pound or ton-mile of work done. "Foot-pound" means the power needed to overcome gravity and lift a pound of matter a foot high, and is a very handy unit for measuring and comparing power. "Ton-mile" is sometimes similarly used and its use thus is easily understood. To return: we said the energy-fuel (food) of animals is far more expensive. The fact is well known; the reason will be explained presently. The fact first: Hay and grain average about $18 per ton; soft coal, including slack, averages about $3, one-sixth as much. Further, a ton of coal will do about six times as much work measured by foot-pounds or ton-miles as a ton of hay and grain. That is, the "energy-fuel" of animals costs 36 times as much in proportion to the work done. Further, the animals must be fed, housed and cared for at nearly equal cost when not at work; but all cost on the engine, both steam and gasoline, practically ceases when its work ceases temporarily. Hence animals are wholly out of the race with steam and gasoline in all heavy work that either of these two can do.

DEEPER REASONS WHY.

"But," you ask, "why is the animal's energy-fuel more costly?" Because it is organic matter, the result of the organic life and growth of the hay and grain, and their growth and harvesting have cost far more human and animal labor (most expensive) than the mining or the pumping of the non-organic or inorganic coal and gasoline. Further, the coal and gasoline are almost wholly carbon, energy-producers, and contain very little water, whereas, (aside from the water in them) about half of the value and cost of the hay and grain are nitrogen, phosphoric acid and potash, which go

to make and maintain the bone, muscle and blood of the animal and not largely to give it force. These are hints as to some of the reasons why animals cannot at all compete with steam or gasoline, wherever the latter two can be used. This confines the profitable use of animal muscle to kinds of moving work that steam and gasoline cannot do to advantage.

HUMAN MUSCLE FOR FARM WORK.

By far the most costly of all forms of power or energy for farm work (or any work that can be done by the other kinds of power mentioned) is human muscle, for reasons to be given presently. And it is well to remark here that many kinds of work once thought possible to be done only by human muscle are now done better and far faster and cheaper by man-devised implements and machines run by far cheaper power than human muscle. Such kinds of work include plowing and horse cultivating instead of spading and hoeing by hand; mowing, tedding, raking, hay-pitching, reaping, binding and threshing grain, wood-sawing, etc. And from the farm home the coloring, knitting, weaving, sewing, garment-making, and many other kinds of former hand-drudgery have now mostly gone to great steam or water power factories where by ingeniously-devised machines it is done many times as fast. And even where the sewing and knitting remain in the farm home the sewing machine and the knitting machine will take ten or twenty stitches while the sewing or knitting needles took one. Compare the old spinning wheel and hand loom with the steam-power spinning jenny or "mule" and the power loom; or the old hand flail and hand "fan" or fanning mill with the steam thresher and separator, with its thousand bushels per day; or the sickle with the twine binding reaper. Human muscle and simple hand tools cannot at all compete with ingenious machines run by animals or by the great forces of Nature.

WHY HUMAN MUSCLE IS THE MOST EXPENSIVE.

Chiefly because its energy-producing food (fuel) and its "keep" are vastly more costly. The engine's food (fuel) as noticed before costs about one-sixth of a cent per pound; the horse's about a cent per pound; the man's costs about 10 to 15 cents per pound on the average, for bread, breakfast food, eggs, meats, tea, coffee, condiments and luxuries. His food costs more because most of it is what we may call "doubly-organized," like meat, eggs, milk, etc. For the animals and fowls eat the "singly-organized" grasses and grains and "organize" them a second time into their bodies and products, which thus become doubly-organized and more expensive, and are eaten by man. Here, then is the gradation of costs. The engine's food (fuel, coal, gasoline) is inorganic, not organized by

life and growth, and costs a sixth of a cent per pound; the animal's food is organic or simply organized by one life and growth and costs about a cent per pound; man's food (fuel, energy-producer) is mostly doubly organized (once by plants, again by animals) and costs from 5 to 40 cents per pound.

Still further, man must have clothing, $100 per year or more. The horse's new suit costs nothing and lasts a full year. The engine needs no clothing at all. The man must have home, warmth, carpets, books, pianos, what not. The horse needs only a barn, the engine only a shed. You see it all. Human muscle costs vastly more, and for clear reasons.

WHAT WE OWE TO THE SUN.

Practically all energy comes from the sun. Its heat and energy, using the materials of earth and air, grew the plants and trees that formed the fuel for the engine's power, and the hay and grain for the horse's energy or power, and the cereals, meats, etc., for man's energy or power. Water power is due to the sun's heat which evaporates the moisture in vast amounts from ocean, lake, river and moist land, holds it in the chambers of the sky, wafts it to the mountains and high lands where it meets colder currents and falls as rain to feed the streams, which, drawn by gravity, seek the sea, turning countless wheels of industry along their courses. King Solomon was right in saying, "All the rivers flow into the sea; yet the sea is not full. Unto the place from whence the rivers came thither they return again."

Again, wind power is due to the sun, whose varying heat in his daily rounds causes the winds to blow, which gives them power. Even gravity is mainly efficient in conveniently using the stored energy of the sun. Human muscle winds up the great hall clock weights, and the muscular energy (originally from the sun) used in one minute in winding or overcoming gravity, is stored, as in a storage battery, and lasts eight days, helping the pendulum to overcome the friction of the wheels and make the clock go. The steam engine whose energy is from the sun lifts the silage against the force of gravity and fills the tall silo in one day, and gravity stands ready for 300 days to use that stored energy in carrying the silage down to the cows. So with the water lifted by the sun to fall on roof of barn or house, gravity reverses the energy in working the water systems of barn and house. So when gravity uses the hillside spring to give running water in house or barn lower down, it can do so only because the sun had previously lifted the spring's water to that higher level. Thus to the sun we owe not only all life and growth of plant and animal, but practically all other forms of power and energy on earth. Professor C. A. Young, the astronomer, says in substance, that if the sun's light and heat and other

forms of energy should cease all activity and life must soon perish on the earth. No wonder the ancient Persians worshipped the sun as God.

WHAT SHOULD ALL THIS TEACH US?

First, deep gratitude for all the materials and the mighty forces of earth and air and sun, and for man's inventive skill that enables him to lay them under tribute for his comfort and welfare. Second, since human muscle, as shown, is immensely the most costly of all forms or sources of power or energy, it should be used only in doing the things that it alone can do; not in laziness but in brain-work in planning how best to use beasts and Nature's mighty inanimate forces in fitting Nature's rich materials to minister to man's well-being.

Scripture intimates that bodily work was sent as a curse and a punishment for sin. Unintelligent labor is still a punishment for the sin of willful ignorance, and as a consequence of the misfortune of unwilling ignorance. But intelligent work, where the trained mind and eye guide the trained hand and body in skillful industry, is a blessing and yields a rich reward. God gave man dominion not only over "the beasts of the field, the fowls of the air and the fishes of the sea," but also over the mighty forces and the rich and boundless materials of Nature. He gave him a thinking mind in order, for one thing, that he might always use the cheapest source of power, on the whole, that can be made to do the given kind of work. It does us good to study into the reasons of things, as we have tried to do, and it is wise to use the results of such study in lightening the labors and increasing the products and the profits of the farm; to use the twine binder and not the sickle, the steam thresher and not the flail, and the great steam engine and special mixing machines and not the hand shovel and sieve in mining fertilizers, and so on for all the processes on the farm and in the home.

CHAPTER XXI.

APPLE GROWING WITH DAIRYING.

For those of our readers who have a taste for fruit culture and will give it proper attention, the growing of first quality winter apples for sale makes a most excellent supplement for dairying, especially for winter dairying. There are several reasons for this. First, the rolling and rather hilly regions where many of those who read this book have their farms and dairies furnish that essential thing for profit in apple-growing, viz., immunity from the May frosts that so often on level ground destroy the apple crop in bloom, or just out of bloom. In the rolling regions the May frosts seek the lower lands, the orchards on the higher land (as they should be) escape, and a fair crop is had in the off years when apples are high. Second, the dairy furnishes excellent strawy manure for enriching and mulching the orchard, above what is needed for silage corn, or by clover turf to be followed by wheat or by oats and wheat, with fertilizer and seeded to clover in rotation. This manure and mulch are very important. Third, the pruning and spraying can be done between morning and evening chores, and the picking and packing come in October after the second crop of clover is all cut and the silage is in the silo. Fourth, the apples of the hilly and rolling region of which eastern Ohio is nearly the western limit, are for texture and flavor unsurpassed in any and equaled in very few localities. The famous high-colored apples of the Pacific Coast are far inferior to ours both in texture and flavor.

"TEN ACRES ENOUGH."

Ten acres with trees set 33 feet apart both ways, making 400 trees, is enough and not too much for a really successful commercial orchard in connection with the dairy. With only two or three acres there is hardly enough of it to pay one to give the necessary time and care to produce the very best quality of fruit—the only kind that sells well—or to advertise and find first class prices and markets. Unless one is willing to run a commercial orchard of about the size, which, when in full bearing, will yield from two thousand to eight or ten thousand bushels per year, he had better not undertake commercial orcharding at all, but content himself with eight or ten trees of as many varieties, of summer, fall and winter kinds, simply for family use. For this purpose the Astrachan or Duchess for summer, the Maiden's Blush and Fall Wine for fall, and the Belmont, Delicious, Rambo, Nonesuch, Spy, R. I. Greening and Baldwin, both for eating and cooking all through the winter, will be a good selection, for latitudes from 40 to 44 degrees.

VARIETIES FOR A COMMERCIAL ORCHARD.

For a commercial orchard in the region north of 40 degrees the Baldwin is the money maker. It is really a very high second-grade apple for eating and first grade for baking, sauce and pies. The Belmont and Delicious are strictly first grade and always sell well but are not great bearers. The R. I. Greening ripens too early for a winter apple south of 41 degrees. The Northern Spy is late in coming to bearing, requires careful pruning and spraying to color well, is a strictly first-class apple and sells well if well colored. The King of Tompkins County is a short-lived tree south of 42 degrees. South of 40 degrees the Rome Beauty and the Ben Davis are probably the best money makers. Both are showy apples, the first a fair second grade, below the Baldwin in quality, but a good seller. The Ben Davis is a handsome, low-grade apple, but is a great bearer, good keeper and a money maker. As to varieties and proportion of each in any latitude or locality it is wisest to follow the advice of successful commercial orchardists in the immediate locality or at least of the same latitude.

Desirable Formation of Head in Apple Trees.

STARTING AN ORCHARD.

It is usually best to get trees two years old and from a near-by nursery if possible. Pack the roots in damp moss or straw and set them while they are still damp. Prune off bruised ends of roots and enough branches to balance loss of roots in transplanting. Dig holes (in plowed land) large enough not to cramp the roots, lean the trees slightly towards the southwest to prevent sun scald and to let the prevailing winds blow them back plumb, sprinkle fine earth around the roots and churn the tree gently up and down to let the earth all around the roots. Fill in the hole, tramp firmly

and mound up around the trunk or guard with fine-mesh galvanized wire screen up 24 inches to protect from mice, rabbits, etc.

HEADING THE TREES.

Our preference is to head the young trees at about four to five feet high. In windy and hot regions many head as low as two feet. Low heading and light pruning tend to dwarf the tree and bring early bearing and maturity, but not to make large trees that will bear 40 bushels each. Never prune to a crotch or let two or three main limbs branch from the same height on the trunk, ending the trunk there. The cut herewith, from a photograph, shows a Baldwin tree four years from its orchard-setting headed properly. Of the six main limbs shown in the picture no two branch from the trunk at the same height, and the trunk is finally all divided up into limbs. This tree has its head formed at about four feet. When it is old enough to bear heavily the fruit will bend the ends of these branches to the ground and make picking easy.

Whoever plans to have a commercial orchard should have and study a good book especially devoted to orcharding, which contains full and judicious information, instruction and advice on every feature of fruit growing.

THE PROFITS OF APPLE-GROWING.

The writer made many mistakes which he would not repeat with his present knowledge gained by later reading and experience. But it is fair to say that his ten-acre orchard on the highest land on the farm, yielded far larger net returns than any other ten acres on his dairy farm, though the strawy manure from the dairy and the wheat straw helped much. For the first 15 years after the 400 trees, mostly Baldwins, had come to full bearing the net income averaged nearly $100 per acre per year on land assessed for taxation at about $50 per acre. "Net" here means the cash received above all costs of picking, barrels, advertising, selling and shipping; but not above cost of pruning, tilling, spraying and the manures and strawy mulch used. As to manures and strawy mulch used, that is the reason why the dairy, the growing of some wheat and oats and a large orchard go so well together.

CHAPTER XXII.

HOME AND FARM ADORNMENT.

It pays to beautify the place where our lives are spent. Here as always we preach what we try to practice. To most of us, especially to women, God has given the love of the beautiful, and more than half of "the joy of living," especially in the country, comes from the enjoyment of rural beauty. Most of the rolling and hilly farms in the regions where this book will be principally read, have fine views from them and rare beauty on them, capable of great in-

Lawn at Home of Author Showing Arrangement of Shrubbery and Trees.

crease by "the art that doth mend Nature," the art of landscape gardening. The view from our farm home of the broad valley of Tinker's Creek and of the gentle slopes on both sides of the creek, and of the cultivated farm homes beyond for five miles, with maple groves here and there, beautiful in the light green of springtime or resplendent in their autumn gold, crimson and purple, with homes and cultivated fields between, is finer than any dead painting that the Vanderbilts or Rockefellers can hang on their walls. We used to enjoy it to the full each day and say to ourselves that the view alone was worth five thousand dollars. It was worth it to us and more than that to a wealthy city man who coveted it, and because of the view, of the orchard and lawn and roadside adornment, paid more than twice as much for the farm per acre as would have

bought other farms near by with as good buildings, but lacking the esthetic features. Such fine views are prized and coveted by many city men, more and more year by year.

OUR LAWNS.

Wealthy city people often pay thousands of dollars for an acre or less on which to create a beautiful velvety lawn with shrubs and flowers, and walks winding among them. But our farm lands will hardly average a hundred dollars per acre. We surely can afford an acre near the house to beautify and make a home, not a mere house, and to gladden our eyes and our souls as we sit and look out from the porch or play tennis on the lawn. Our house when we bought the place, some 50 years ago, stood about 40 feet from the street line, and so most of the lawn had to be at the south side. A small old orchard was premitted to remain until 1890 for its fruit. When the large young orchard had come to bearing the old unsightly trees of the old one were grubbed out and the land cultivated a year. We decided upon the general features of the lawn and paid a landscape artist about $10 to draw a careful sketch and to suggest suitable trees, shrubs and flowers. The result was in part as in the picture herewith from a photograph taken in 1898, only seven years from the time the shrubs and the trees (except two) were set. There are eleven kinds of evergreen trees and shrubs of varying shades, and thirteen kinds of deciduous ones. My wife soon had over 20 kinds of roses, blooming all the spring, summer and fall, and some sort of flowers or flowering shrubs in blossom from the time the first tulip, narcissus and crocus thrust their buds up through the snows of early spring to the time the last chrysanthemums, asters and dahlias defy the early frosts and snows of autumn. Why not? We and the children loved them all and the beauty of the lawn. Their care, with a man to do the heaviest work, was a delight and a health-giving power, and cost far less than doctor's bills. Examine the picture and remember that all the trees and shrubs in sight, except two, were brought from the nursery 30 miles away only seven years before at one load in a two-horse spring wagon, besides quite a number not shown in the picture. The two exceptions are the tall elm at the right front near the house and the queer old apple tree seen in the rear at the left. The former was set the same spring, taken up early, near by, eight inches through at the butt, 30 or 40 feet high and with a ton or so of frozen earth around the roots. The other, the apple tree, was saved from the old orchard for its queer shape and its delicious fruit. The front of the lawn, towards you, does not show the great elm nor any of the roadside maples shown in the next picture. The open vistas from the road show the dense ornamental windbreak of several kinds and shades of evergreens, in the rear to the north-

west and running around to the southwest, backed on both sides by the large young orchard whose trees in 1898 were in full bearing and were tall enough to be seen above the tops of the evergreens. This double windbreak of the evergreens and of the orchard is a

Shaded Road, Hedges, Orchard and Parked Roadsides along Farm of the Author.

great comfort during the fierce winds and storms of fall, winter and spring. In the years before either was grown the fierce winds often shook the house and it seemed sometimes as if they would blow it away. Now there is no such trouble and the house is far more easily warmed in cold, windy weather. There is an open outlook to the south and east, whence fierce winds and storms seldom come.

ROADSIDE ADORNMENT.

When my wife and I bought my father's farm and moved onto it in 1864, it had been "rented out" for about 12 years and was in forlorn condition. Mud roads made the people drive on the sides and ruin the grass borders. We soon set the roadside maples and hedges shown in the picture and soon a smooth, hard, limestone slag road was built by ourselves and neighbors with $400 help from the county and township. This took away all temptation to drive

on the roadsides, and so we plowed, graded, manured and seeded them. By 1910 the maples were a foot through and the grass heavy so that the maple syrup and the hay from the roadside brought about $60 per year. Why not? The road land belongs to the farmer, paid for when he buys his farm, subject only to necessary travel which, with good stone road, is all confined to 16 feet wide in the middle, leaving 22 feet wide on each side for nearly half a mile (in our case) for the trees and the grass. The picture, looking due northeast on a diagonal road, shows the slag road, the trees and the hedge on each side, and the orchard inside and beyond the hedge on the left. On the right between the trees and the hedge is the beautifully shaded sawed flagstone sidewalk, 44 inches wide, made by a wealthy neighbor aided by one other neighbor and ourselves. It extends half a mile southwest from our farmhouse to the old corporation line, from whence a half mile more to the main business street a village tax had already laid a similar walk; a full mile of cool, shaded flagstone walk. The trees are now, in 1916, far larger than they are shown in the picture, which was taken 18 years ago, in 1898. As a whole I think I have never seen a more beautiful stretch of country road, and I have traveled in most of the United States and in tho principal countries of Europe. And the beauty cost nothing. The syrup and the hay pay for it all except the flagstone walk, and the Osage hedges are cheap and most serviceable and lasting fences if properly pruned and kept low and narrow. A large part of those seen in the picture are now over 50 years old and apparently good for 50 years more. All this is given simply as a sample of what many other farmers might do and some have done. It pays in beauty and in cash!

CHAPTER XXIII.

THE FARMER AS A MAN.

THE FARMERS' CLUB, THE GRANGE, ETC.

First of all, the farmer is a man; and it goes almost without saying that he and his family should be active parts and factors of the social, educational, political and religious life of his neighborhood, town, county, state and nation. He and his wife and older children should be active members of the local farmers' club or grange, that they may both get and give benefits. He should stand ready but not eager to act as township trustee and work for good roads and other township improvements; as school director, to promote good schools; and as a member of his local village church to help promote morality, social life and public betterment.

THE CHURCH AND ITS ACTIVITIES AND CLUBS.

I do not believe any intelligent farmer can afford not to attend church regularly or not to be a sharer in its good work, whether his intellect approves of all the old and rather rigid theology or not. The church creeds nowadays simply ask the members to believe in the righteous and loving government of God in this world, and the covenants ask the members to practice and try to promote right and rational living as taught and practiced by the Man of Nazareth.

As to the refining and educational effect of church attendance, Dr. J. G. Holland, who for many years and until his death was editor of Scribner's and of The Century magazines, says this in substance in one of his books. I quote from memory as follows: "My friend, especially my country friend, you cannot afford not to attend church. The music and the common worship uplift and strengthen for better work and service in life. The preaching is helpful. The minister has had from seven to ten years of special study and preparation for his work, and at very heavy expense. He spends the most of six days of each week in studying the needs of his people and in preparing a message that shall be helpful to them. Presumably he has something each Sunday well worth hearing. You cannot afford to miss it for yourself and for your family."

THE SABBATH AS A DAY OF REST.

For myself I can say that through my life of nearly eighty years, chiefly as a farmer, and all of it among farmers, I have noticed that the farm children who have been trained to "remember the Sabbath day," attend church and attend Sabbath School, and try to keep the Golden Rule, have grown up to be more successful and respected men and women and better and more helpful citizens

than the farm children who have not been trained up to attend church, but have like their parents made the Sabbath a day for lounging or loafing or for hunting, fishing, baseball and the like. Such boys I have often seen "go to the bad." The people who work for the best things for the community, as a rule, are the church goers. Of course there are exceptions. Then, too, in most rural and village communities the best and most enjoyable social, musical and literary life and activity cluster around the local churches and the various organizations connected with them. The farmer and his family cannot afford to neglect these great social, intellectual and moral influences.

Some way or other Moses seems to have hit it about right when he commanded the Israelites, who had known little rest in Egypt, when freed from bondage to "rest from all their labors" one day in each seven. The human system seems to require about as much rest as that besides the night's rest. The most prosperous nations are those that take it—the Christian nations. At the time of the great French Revolution the Sabbath was "abolished" and one day in ten was made a legal day of rest. But it was soon found not to be enough and the French before long practically got back to the seven-day plan of Moses. Further, it seems wisest, especially for farmers and other bodily workers, to rest largely from bodily exertion, to take the time for mental and moral and social growth and enjoyment of a sort that really re-creates and fits for future service and not of a sort that excites and wearies and makes the duties of Monday and the other days of the week a drudgery and a dread.

The End.

INDEX

Adornment,
  Home and roadside.. 82
  Roadside 83
Albuminoids 8, 10
Ammonia 8, 10, 65
Apples,
  Desirable formation of head in trees... 80
  Profits 81
  Ten acres enough... 79
  Varieties 80
  With dairying 79
Bacteria 37
Barn,
  Dairy 58, 59
  Drop or gutter 60
Cabbage 30
Carbohydrates 7
Carbon 12, 16
Carbonic acid 9, 16
  Work of 22
Celery 30
Chili saltpeter 65
Church 86
Clay,
  Boulder 25, 27
  Drift 27
Clovers 35
  Action of 36
  Importance of 37
  Why not use more?. 38
Clubs 86
Condensation of plant food....... 62
Crops
  "Fed" 34
  Fiber or clothing... 33
  Food and Feed 32
  "Money" 83
  Ornamental or flowering 83
  Partly sold 34
  Rotation of 41, 48
  Season 40
  Timber 83
Crust,
  What crumbled earth's rocky?..... 21
Drainage 80
Drouth,
  To resist 41
Dairy,
  Barn 58, 59
Elements,
  Essential 8
Energy 70
Exertion 87
Experiments
  Rothamstead 88, 50
Fertility,
  Keeping up 54
Fertilizers,
  Buying 67
  Commercial 62
  Home-mixed 68
  Sources of 63
Food,
  Available 49
  Condensed 62
  "Energy" 7, 8
  Found in air 15
  Found in soil 18
  Inorganic 15
  Organic 7
  Plant 7
Foot-pound 75
Fundamentals in farming 89
Gasoline 73
Glacial action 24
  Effects of 25
  Extent of 26
Gravity 71, 72
Guano 65
Holland, Dr. J. G..38, 86
Humus 18, 66
Hydrogen 13
Ice,
  Work of 22
Implements 46
  Bull-tongue cultivator 47
  Clod-crusher 47
  Disc cultivator 47
  Plow 46
  Roller 47
Income 57
Iron 13
King System 60
Lawns 83
Lettuce 30
Lime 9, 12
Loess 22
Machine,
  Understanding a ... 21
Magnesia 13
Man,
  Farmer as a 86
Manures,
  Cattle 55
  Dairy 56
  Farm supply of..... 51
  Liquid vs. solid ... 53
  Making, saving and using 54
  Market for 54
  Mixing in drop 61
  Pigs 56
  Per animal 53
  Poultry 55
  Sheep 54
  Value 52
  Use of 53
  Waste of 40
Moisture,
  Film 39, 40
Nitrates 9
Nitric acid 9
Nitrogen ....9, 10, 16, 37, 64,.......... 68
Nodules 37
Onions 80
Orchard,
  Commercial 80
  Starting an 80
Oxygen,
  Work of 22
Pests,
  Insect and fungous.. 49
Phosphoric acid 9, 68
  Sources 64
Phosphorus 10
Plants,
  Agricultural 31
  Annuals 38
  Biennials 33
  Classifications of..31, 32
  Deep-feeders 49
  Perennials 33
  Recuperative 35
  Useless or harmful.. 31
  Useful 32
  Work of 23
Potash 9, 10
  Deposits 65, 66
  Muriate of 65
  Sulphate of 65
Power, farm 70
  Animal 75
  Electrical 70
  Forms of 70
  Steam 74
  Water 70, 72
  Wind 72
Productiveness,
  Increasing 51
Profits,
  In apples 81
Protein 8, 10, 68
Pulverization 41
Rock,
  Aqueous 19
  Igneous 19
  Metaphoric 20
Root hairs 14
  Pasturage of 40, 42
Rotation 41, 48
Science, experience confirms 48
Sabbath 86
Soil,
  Alluvial 28
  Clayey 29
  Drift 26, 28
  Exhaustion 33, 48
  Gravelly 29
  Kinds of 28
  Lacrustrine 29
  Loamy 30
  Muck 30
  Peat 30
  Sandy 29
  Sedentary 28
  Subsoil 19
  Transported 28
  What it is, how formed, etc. 18
Second bottoms 28
Seeds,
  Distribution of 32
Streams,
  Work of 22
Sulphur 18
Sun,
  Work of the 22
  What we owe the .. 77
"Ten acres enough" (apple) 79
"Till" 25
Tillage 41, 42, 44
Ton-mile 75
Trees (apple)
  Heading 81
Ventilation
  Barn 60
Water
  Capillary 39
  Farm 70
  "Free" 39
  "Ground" 39, 41
  Original purpose of. 32
  Surplus 39
  Weeds 31, 49
  Work of 22
Winter-killing 41
Work,
  Farm 49
  Gasoline for 73
  Human muscle for.. 76
  Why expensive 76

End of Title